International Telecommunication Union

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Radiocommunication Sector of ITU

Recommendation ITU-R M.2092-01

(100396649/201765)

Technical characteristics for a VHF data exchange system in the VHF maritime mobile band

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M Series

Mobile, radiodetermination, amateur and related satellite services

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International Telecommunication Union

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***Note**: This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.*

Electronic Publication
Geneva, 2015

RECOMMENDATION ITU-R M.2092-0*, **

Technical characteristics for a VHF data exchange system in the VHF maritime mobile band

(2015)

Scope

This Recommendation provides the technical characteristics of a VHF data exchange system (VDES) which integrates the functions of VHF data exchange (VDE), application specific messages (ASM) and the automatic identification system (AIS) in the VHF maritime mobile band (156.025-162.025 MHz).

Keywords

Maritime, VHF, VDES, ASM, data, exchange

Abbreviations/Glossary

3GPP	Third generation partnership project
ACK	Acknowledgement
ADDC	Assigned data transfer
ACPR	Adjacent channel power ratio
AIS	Automatic identification system
AOS	Acquisition-of-signal
APSK	Amplitude phase shift keying
ARQ	Automatic repeat request
ARSC	Announcement response channel
ASC	Announcement signalling channel
ASM	Application-specific messages
ATDMA	Allocated Time-Division Multiple Access
AWGN	Additive white Gaussian noise
BBSC	Bulletin board signalling channel
BCH	Bose Chaudhuri Hocquenghem, an error-correcting-code
BER	Bit error rate
BPSK	Binary phase shift keying
BT	Bandwidth-time
CEPT	European conference of postal and telecommunications administrations

* The use of some frequencies in the band 156-164 MHz, contained in this Recommendation, do not comply with the RR currently in force. This Recommendation therefore should not be seen as prejudging the decisions of WRC-15. ITU-R Study Group 5 is invited to review this Recommendation taking into account the decisions made by WRC-15.

** Note by the BR Secretariat – The figures in this Recommendation are available in English only. The other languages will be prepared in due course.

CDMA	Code division multiple access
CG	Coding gain
CIR	Carrier to interference ratio
C/M	Carrier to multipath
CNR	Carrier to noise ratio
COMSTATE	Communication state
Control Station	Coast base station, satellite or other VDES station that is transmitting bulletin board and provides routing services to the maritime cloud
CPM	Continuous phase modulation
CQI	Channel quality indicator
CR	Code rate
CRC	Cyclic redundancy check
CRL	Configuration revision level
CS	Carrier sense
CIRM	Comité international radio maritime
CSTDMA	Carrier sense time division multiple access
CW	Continuous wave
DA	Doherty amplifier
DLS	Data link service
DPD	Digital pre-distortion
EDN	End delivery notification
EDF	End delivery failure
EIRP	Equivalent isotropic radiated power (e.i.r.p.)
ERP	Effective radiated power (e.r.p.)
ET	Envelope tracking
FATDMA	Fixed access time-division multiple access
FCS	Frame check sequence
FEC	Forward error correction
FIFO	First-in first-out
GMSK	Gaussian-filtered minimum shift keying
GNSS	Global navigation satellite system
HS	Hexslots
IALA	International association of marine aids to navigation and lighthouse authorities
ICAO	International civil aviation organization
ID	Identification
IEC	International electrotechnical commission
IMO	International maritime organization
IP	Internet protocol
ITDMA	Incremental time division multiple access
LC	Logical channels

LEO	Low-earth orbiting
LFSR	Linear feedback shift register
LME	Link management entity
LNA	Low noise amplifier
LOS	Loss-of-signal
LSB	Least significant bit
MEO	Medium-earth orbiting
MAC	Media access control
MCS	Modulation and coding scheme
MDC	Multicast data channel
MMSI	Maritime mobile service identity
MSB	Most significant bit
NF	Noise figure
NM	Nautical mile
NRZI	Non-return to zero inversion
OFDM	Orthogonal frequency division multiplexing
OSI	Open systems interconnection
PAPR	Peak to average power ratio
PC	Physical channels
PL	Physical layer
PFD	Power flux-density
ppm	parts per million
PSK	Phase shift keying
QAM	Quadrature amplitude modulation
QPSK	Quadrature phase shift keying
RADC	Random access short messaging channel
RATDMA	Random access time-division multiple access
RAC	Random access channel
RF	Radio frequency
RSC	Recursive systematic convolutional
RQSC	Random access resource request
RR	Radio regulations
RSSI	Received signal strength indication
SCTDMA	Slot carrier sense time division multiple access
SFTP	Secure file transfer protocol
SI	Selection interval
SMTP	Simple mail transfer protocol
SNMP	Simple network management protocol
SNR	Signal to noise ratio
SOLAS	Safety of life at sea convention

SOTDMA	Self-organized time division multiple access
SS	Spreading sequences
Sym	Symbol
SYNC	Synchronization
TBB	Terrestrial bulletin board
TBBSC	Terrestrial bulletin board signalling channel
TDMA	Time division multiple access
UDC	Unicast data channel
UDP	User data protocol
UTC	Coordinated universal time
VDE	VHF data exchange
VDES	VHF data exchange system
VDE-SAT	VHF data exchange-satellite
VDL	VHF data link
VHF	Very high frequency

References

{RD-1} ETSI EN 302 583 (V1.2.1) – Digital Video Broadcasting (DVB); Framing Structure, channel coding and modulation for Satellite Services to Handheld devices (SH) below 3 GHz.

{RD-2} TM Synchronization and Channel Coding. Recommendation for Space Data System Standards, CCSDS 131.0-B-2. Blue Book. Issue 2. Washington, D.C.: CCSDS, August 2011.

{RD-3} R. Mueller, On Random CDMA with Constant Envelope, ISIT 2011.

{RD-4} Recommendation ITU-R P.372 – Radio Noise.

{RD-5} Recommendation ITU-T V.42 (03/2002) – Series V: Data Communication over the Telephone Network – Error control – Error-correcting procedures for DCEs using asynchronous-synchronous conversions.

The ITU Radiocommunication Assembly,

considering

a) that the International Maritime Organization (IMO) has a continuing requirement for a universal shipborne automatic identification system (AIS);

b) that the use of a universal shipborne AIS allows efficient exchange of navigational data between ships and between ships and shore stations, thereby improving safety of navigation;

c) that the VHF data exchange system (VDES) should use appropriate access schemes that ensure the protection of AIS while making efficient use of the spectrum and accommodate all users;

d) that while AIS is used primarily for surveillance and safety of navigation purposes in ship-to-ship use, ship reporting and vessel traffic services applications, a growing need for other maritime safety related communications has developed;

e) that the VDES shall give priority to AIS, and also accommodate future expansion in the number of users and diversification of data communications applications, including vessels which are not subject to IMO AIS carriage requirements, aids to navigation and search and rescue;

f) that the VDES has data communications capacity and technical characteristics that support the harmonized collection, integration, exchange, presentation and analysis of marine information on board and ashore by electronic means to enhance berth to berth navigation and related services for safety and security at sea and protection of the marine environment,

recognizing

that the implementation of VDES must ensure that the functions of digital selective calling, AIS and voice distress, safety and calling communication (Channel 16), are not impaired,

noting

that Report ITU-R M.2371 describes the use cases and requirement for VDES,

recommends

1 that VDES should be designed in accordance with the operational characteristics given in Annex 1 and the technical characteristics and examples given in Annexes 2 to 7;

2 that applications of the VDES which make use of application specific messages (ASM) designed for AIS, as defined in Recommendation ITU-R M.1371 should also take into account the international application identifier branch, as specified in IMO SN.1/Circ. 289, maintained and published by IMO;

3 that the design and installation of VDES should also consider relevant technical requirements, recommendations and guidelines published by IMO, IEC and IALA.

Annex 1

Operational characteristics of a VHF data exchange system in the VHF maritime mobile band

1 General

1.1 The system should give its highest priority to the automatic identification system (AIS) position reporting and safety related information.

1.2 The system installation should be capable of receiving and processing the digital messages and interrogating calls specified by this Recommendation.

1.3 The system should be capable of transmitting additional safety information on request.

1.4 The system installation should be able to operate continuously while under way, moored or at anchor.

1.5 The system should use for the terrestrial links time-division multiple access (TDMA) techniques, access schemes and data transmission methods in a synchronized manner as specified in the Annexes.

1.6 The system should be capable of various modes of operation, including the autonomous, assigned and polled modes.

1.7 The system should provide flexibility for the users in order to prioritize some applications and, consequently, adapt some parameters of the transmission (robustness or capacity) while minimizing system complexity.

1.8 The system should address the use cases identified in Report ITU-R M.2371.

2 General description of the VDES

The VDES provides a variety of means for the exchange of data between maritime stations, ship-to-ship, ship-to-shore, shore-to ship, ship-to-satellite and satellite-to-ship. The VDES functionally includes the AIS, either by integration, by interface connection or by radio frequency connection.

23 VHF data exchange system functions and frequency usage

The VDES functions and frequency useage are illustrated pictorially in Figure A1-1.

3.1 Identification <TODO item 112: ROSS to incorporate this moved chapter>

Identification and location of all active maritime stations is provided automatically. All VDES stations should be uniquely identified. For the purpose of identification, the appropriate numerical identifier, for example maritime mobile service identity (MMSI), could be used, as defined in the latest version of Recommendation ITU-R M.585. Recommendation ITU-R M.1080 should not be applied with respect to the 10th digit (least significant digit).

3.4 Presentation interface protocol <TODO item 112: ROSS to incorporate this moved chapter>

For VDES transceivers:

– data may be input via the presentation interface to be transmitted by the VDES station;

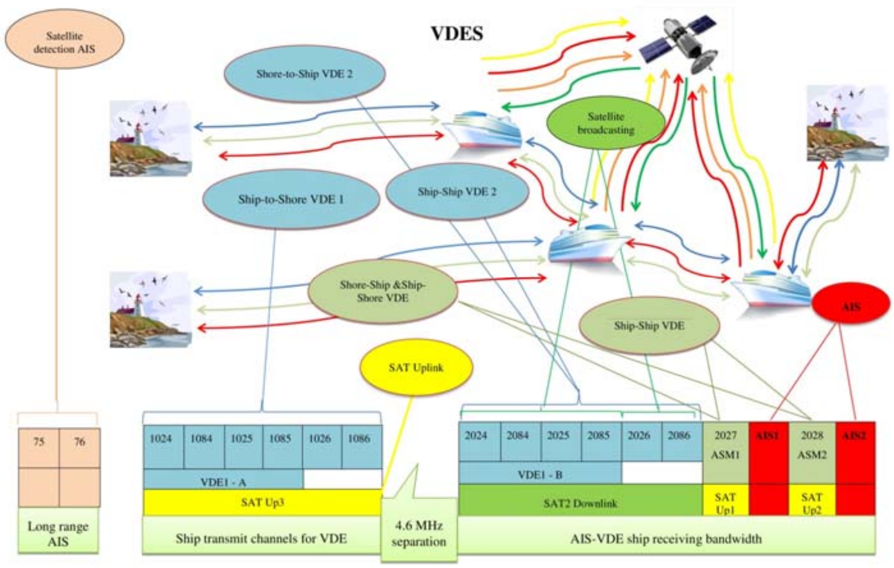
– data received by the VDES station should be output through the presentation interface.

VDES functions and frequency usage are illustrated pictorially in Fig. A1-1.

Figure A1-2 1 illustrates the VDES defined in this Recommendation from a system engineering perspective.

FIGURE A1-1

VHF data exchange system functions and frequency usage



NOTE – SAT Up is receive-only by satellite.

2.13.1 VHF data exchange system channel usage in accordance with RR Appendix 18

2.1.13.1.1 VHF data exchange system: data exchange between terrestrial stations

– AIS 1 (channel 2087) and AIS 2 (channel 2088) are AIS channels, in accordance with Recommendation ITU-R M.1371

– ASM 1 (channel 2027) and ASM 2 (channel 2028) are the channels used for application specific messages (ASM)

– VDE1-A lower legs (channels 1024, 1084, 1025, 1085) are ship-to-shore VDE

– VDE1-B upper legs (channels 2024, 2084, 2025, 2085) are shore-to-ship and ship-to-ship VDE.

23.1.2 VHF data exchange system: data exchange between satellites and terrestrial stations

– AIS 1 (channel 2087) and AIS 2 (channel 2088) are terrestrial AIS channels that are also used as uplinks for receiving AIS messages by satellite

– Long Range AIS using channel 75 and channel 76 are specified channels to be used as uplinks for receiving AIS messages by satellite. SAT Up1 (channel 2027) and SAT Up 2 (channel 2028) are used for receiving ASM by satellite

– SAT Up3 (channels 1024, 1084, 1025, 1085, 1026 and 1086) are used for ship-to-satellite VDE uplinks

– SAT Downlink (channels 2024, 2084, 2025, 2085, 2026 and 2086) are used for satellite-to-ship VDE downlinks.

3.2 Identification <TODO item 112: ROSS to incorporate this moved chapter>

Identification and location of all active maritime stations is provided automatically by means of the AIS. All VDES stations should be uniquely identified. For the purpose of identification, a unique the appropriate numerical identifier is used as defined by the following:, for example maritime mobile service identity (MMSI), should be used, as defined in the latest version of Recommendation ITU-R M.585. Recommendation ITU-R M.1080 should not be applied with respect to the 10th digit (least significant digit).

If the unique identifier has a range which is less than 999999999, then this number is defined by the latest version of Recommendation ITU-R M.585.

If the unique identifier has a range which is greater than 999999999, then this is number is free form.

3.3 Presentation interface protocol <TODO item 112: ROSS to incorporate this moved chapter>

For VDES transceivers:

– data may be input via the presentation interface to be transmitted by the VDES station;

– data received by the VDES station should be output through the presentation interface.

2.1.33.4 Technical characteristics

2.1.3.13.4.1 Shipborne VHF data exchange system receivers are protected

As in AIS, shipborne VDES receivers are on the upper legs of RR Appendix **18**, 4.6 MHz above the lower legs, which facilitates protection by filtering from receiver blocking by ships VHF radios.

2.1.3.23.4.2 SAT Downlink

The satellite downlink complies with the power flux-density (PFD) mask described in Table A4-1 to minimize interference to terrestrial services and to maximize reception by ship VDES stations.

2.1.3.33.4.3 VDE1 uses both legs of the duplex channels

Channel capacity is utilized for the duplex channels in VDE1 by using the lower legs (VDE1-A) for ship-to-shore and the upper legs (VDE1-B) for shore-to-ship and ship-to-ship digital messaging.

Table A1-1 describes the RR Appendix **18** channels used for the various applications of VDES.

TABLE A1-1

RR Appendix 18 channels for VHF data exchange systems applications: Automatic identification system, application specific messages, VHF data exchange

RR Appendix 18 channel number		Transmitting frequencies (MHz)	
		Ship stations (ship-to-shore) (long range AIS) Ship stations (ship-to-satellite)	Coast stations Ship stations (ship-to-ship) Satellite-to-ship
AIS 1		161.975	161.975
AIS 2		162.025	162.025
75 (long range AIS)		156.775 (ships are Tx only)	N/A
76 (long range AIS)		156.825 (ships are Tx only)	N/A
2027 (ASM 1)		161.950 (2027)	161.950 (2027)
2028 (ASM 2)		162.000 (2028)	162.000 (2028)
24/84/25/85 (VDE 1)	24/84/25/85/26/86 (Ship-to-satellite, satellite-to-ship)	100/150 kHz channel (24/84/25/85, lower legs (VDE1-A) merged) Ship-to-shore (24/84/25/85/26/86) Ship-to-satellite	100/150 kHz channel (24/84/25/85, upper legs (VDE1-B) merged) Ship-to-ship, Shore-to-ship (24/84/25/85/26/86) Satellite-to-ship
24	24	157.200 (1024)	161.800 (2024)
84	84	157.225 (1084)	161.825 (2084)
25	25	157.250 (1025)	161.850 (2025)
85	85	157.275 (1085)	161.875 (2085)
	26	157.300 (1026)	161.900 (2026)
	86	157.325 (1086)	161.925 (2086)

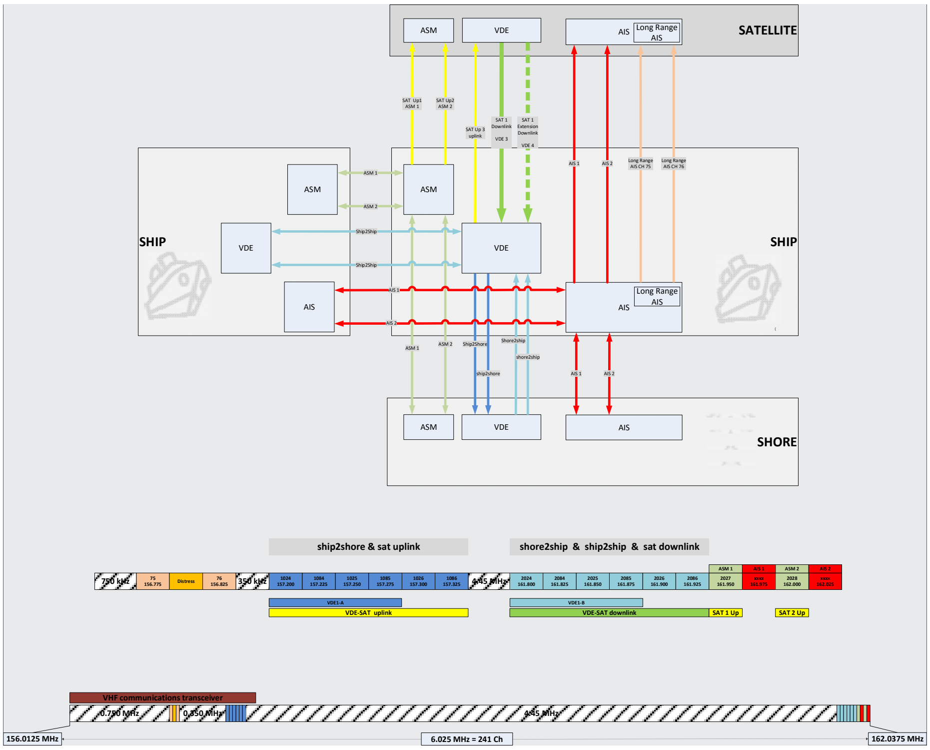
3.4.4 VHF data exchange system functions and frequency usage engineer's perspective

The VDES functions and frequency useage from an engineer's perspective are illustrated pictorially in Figure A1-2.

RR Appendix 18 channel number		Transmitting frequencies (MHz)	
		Ship stations (ship-to-shore) (long range AIS) Ship stations (ship-to-satellite)	Coast stations Ship stations (ship-to-ship) Satellite-to-ship
AIS 1		161.975	161.975
AIS 2		162.025	162.025
75 (long range AIS)		156.775 (ships are Tx only)	N/A
76 (long range AIS)		156.825 (ships are Tx only)	N/A
2027 (ASM 1)		161.950 (2027)	161.950 (2027)
2028 (ASM 2)		162.000 (2028)	162.000 (2028)
24/84/25/85 (VDE 1)	24/84/25/85/26/86 (Ship-to-satellite, satellite-to-ship)	100/150 kHz channel (24/84/25/85, lower legs (VDE1-A) merged) Ship-to-shore (24/84/25/85/26/86) Ship-to-satellite	100/150 kHz channel (24/84/25/85, upper legs (VDE1-B) merged) Ship-to-ship, Shore-to-ship (24/84/25/85/26/86) Satellite-to-ship
24	24	157.200 (1024)	161.800 (2024)
84	84	157.225 (1084)	161.825 (2084)
25	25	157.250 (1025)	161.850 (2025)
85	85	157.275 (1085)	161.875 (2085)
	26	157.300 (1026)	161.900 (2026)
	86	157.325 (1086)	161.925 (2086)

FIGURE A1-2

VHF data exchange system functions and frequency usage engineer's perspective



4 Functions of the VDES

The priority and timing of transmissions shall be in accordance with the following service priorities:

Highest Priority 1: AIS transmissions on AIS channels

Priority 2: specified and approved ASM transmissions on ASM channels

Priority 3: all other data exchange on VDE channels

The VDES receivers shall always be active. It is understood that transmissions by own equipment will impair reception by own equipment on own ship.

The VDES should support the following:

4.1 Automatic Identification System

The AIS will operate as defined by Recommendation ITU-R M.1371.

4.2 Application-Specific Messages – Annex 2

Annex 2 describes the characteristics of the ASM channel that will support applications specific messages in order to improve the efficiency of application-specific message transmissions and to protect the original function of the AIS.

Commenté [SPI1]: item169:corrected ASM2 frequency to 162.000 (was 162.200)

4.3 VDE terrestrial – Annex 3

Annex 3 describes the characteristics of the VDE terrestrial channels providing an efficient terrestrial data transfer link enabling a wide variety of applications for the maritime community.

4.4 VDE satellite – Annex 4

Annex 4 describes the characteristics of a satellite downlink that will support multi-cast multi-package data transfers and shore originated unicast multi-package data transfers via satellite.

4.65 VDES sharing options – Annex 6

Annex 6 describes the characteristics necessary for each component of the VDES to share the available spectrum such that impact between services is minimized and AIS is respected.

4.76 VDES original design considerations – Annex 7

Annex 7 is an informative annex that provides additional information on the technical consideration of the VDES. It identifies aspects of both terrestrial and satellite VDE components, including access scheme options, antenna designs, and system sharing.

35 Common technical Elements elements of the VDES

This section describes those elements of the VDES that may be common across the ASM and VDE channels.

Commenté [SP2]: Item98

3.1 Identification

Identification and location of all active maritime stations is provided automatically. All VDES stations should be uniquely identified. For the purpose of identification, the appropriate numerical identifier, for example maritime mobile service identity (MMSI), could be used, as defined in the latest version of Recommendation ITU-R M.585. Recommendation ITU-R M.1080 should not be applied with respect to the 10th digit (least significant digit).

33.1 Identification

Identification and location of all active maritime stations is provided automatically. All VDES stations should be uniquely identified. For the purpose of identification, the appropriate numerical identifier, for example maritime mobile service identity (MMSI), could be used, as defined in the latest version of Recommendation ITU-R M.585. Recommendation ITU-R M.1080 should not be applied with respect to the 10th digit (least significant digit).

5.21 Protocol layer overview

The VDES architecture should utilize the open systems interconnection layers 1 to 4 (physical layer, link layer, network layer, transport layer) as illustrated in Fig. A1-3.

FIGURE A1-3

Seven layer OSI model

Application layer
Presentation layer
Session layer
Transport layer
Network layer
Link layer
Physical layer

Responsibilities of the OSI layers for preparing VDES data for transmission:

5.2 Physical layer [changed SP to heading 2]

This layer provides transmission and reception of raw bit streams over a physical medium including signal modulation, filtering/shaping upon transmission, and amplification, filtering, time and frequency synchronization, demodulation, and decoding upon reception.

5.2.1 Transmission accuracy figures [changed SP to heading 3]

5.2.1.1 Symbol timing accuracy (at the output)

The timing accuracy of the transmit signal should be better than 5 ppm.

5.2.1.2 Transmitter timing jitter

The timing jitter should be better than 5% of the symbol interval (peak value).

5.2.1.3 Slot transmission accuracy at the output

The slot transmission accuracy should be better than 100 µs peak relative to UTC time reference for ship stations.

5.2.2 Frame Structure [changed SP to heading 3]

The system uses the Recommendation ITU-R M.1371 concept of a frame. A frame equals one (1) minute and is divided into 2 250 slots. Access to the data link is, by default, given at the start of a slot. The VDES frame structure is identical and synchronized in time to UTC (as in AIS). The general slot formats are is shown in Fig. A1-4A and B. ~~Note that “Sync 2” and “Link Configuration Id” are not used by the SAT link.~~ The slot structure for each service is shown in Fig. A1-4~~5~~. Each element is described in Table A1-X in section 5.2.7.~~ the subsequent sections.~~ Table A1-2 shows the resulting net bitrates (Data bits of the slot structure).

FIGURE A1-4A AMSM-TER AND VDE-TER GENERAL PACKET FORMAT

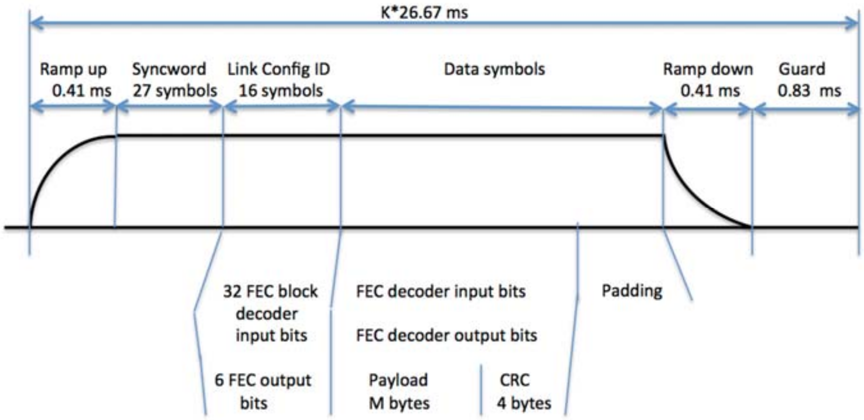
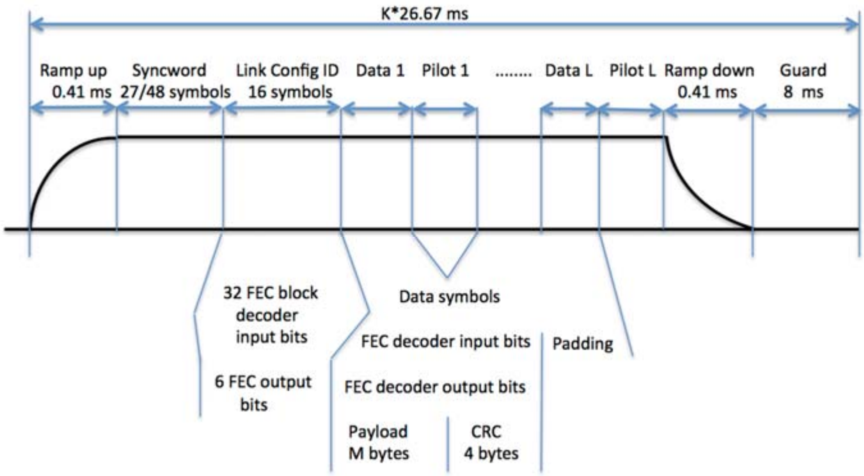
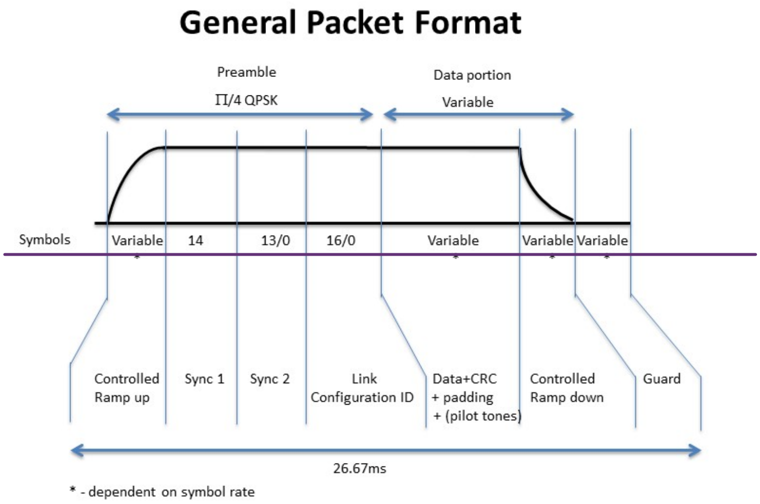


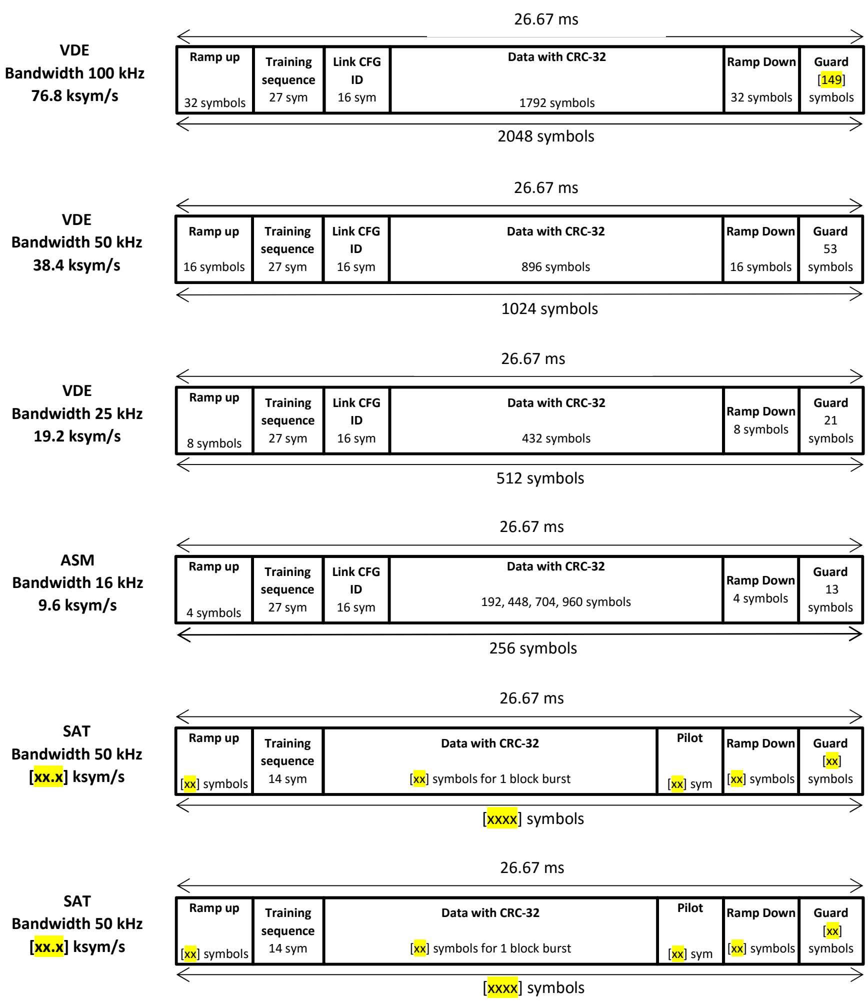
FIGURE A1-4B ASM-SAT AND VDE-SAT GENERAL PACKET FORMAT




General Packet Format
Preamble
Π/4 QPSK
Data portion
Variable
Symbols
Variable
14
13/0
16/0
Variable
Variable
Variable
Controlled Ramp up
Sync 1
Sync 2
Link Configuration ID
Data+CRC + padding + (pilot tones)
Controlled Ramp down
Guard
26.67ms
* - dependent on symbol rate

~~FIGURE A1-5~~

~~Slot structure~~

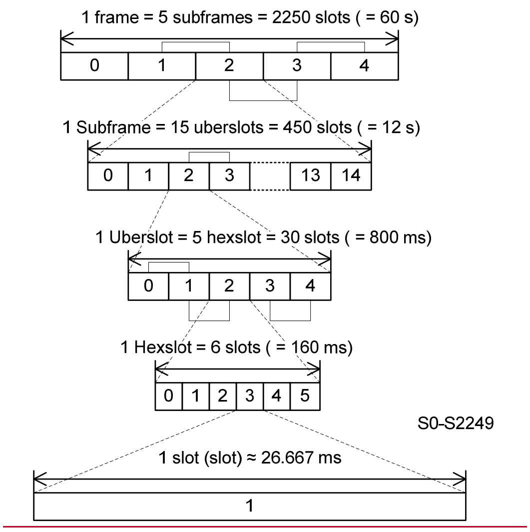


5.2.2.1 Frame hierarchy definition [changed SP to heading 4]

The frame hierarchy is shown in Fig. A1-~~6~~5. The frame hierarchy definition is independent of the assigned bandwidth to the VDE channel

FIGURE A1-~~6~~5

Frame Hierarchy for shared frequency



5.2.2.1.1 Slot [changed SP to heading 5]

The slot is a time interval of approximately 26.667 ms (60 000 / 2 250 = 80/3 ≈ 26.667).

~~The slot should be numbered by a slot number.~~ The slot should be cyclically numbered by a slot number ranging from 0 to 5.

Commenté [SPI3]: merged 2 sentences and removed yellow.

5.2.2.1.2 Hexslot [changed SP to heading 5]

Six slots should form a Hexslot (HS). The HS has duration of 160 ms.

The HS should be numbered cyclically from 0 to 4. The HS should be incremented after every 6 slots.

5.2.2.1.~~4~~3 Uberslot [changed SP to heading 5]

Five Hexslots should form a Uberslot (US). The US should have duration of 800 ms.

The US should be numbered by a US Number. The US should be cyclically numbered from 0 to 14. The US should be incremented whenever the Hexslot returns to 0.

5.2.2.1.~~5~~4 Sub frame [changed SP to heading 5]

Fifteen US should form a sub frame. The sub frame should have a duration of 12 seconds. The sub frame should be numbered by a sub frame number. The PL-frame should be cyclically numbered from 0 to 4. The sub frame should be incremented whenever the US returns to 0.

Commenté [SPI4]: PL-frame what's that?

5.2.3 Burst transmission structure [changed SP to heading 3]

5.2.3.1 Ramp up

The ramp up time from −50 dBc to −1.5 dBc of the power shall controlled rise time and occur in 416 µs. A gradual ramp-up period provides important spectral shaping to reduce energy spread outside the desired signal modulation bandwidth, and reduces interference to other users of the current and adjacent channel. The Ramp-up pattern shown in TABLE A1-1A is mapped like defined in section 5.2.3.3 Bit mapping for training sequence.

TABLE A1-1A. RAMP-UP SYMBOL PATTERNS FOR VDES

Link Config ID		Ramp-Up Time (ms)	Ramp-Up # of transmission symbols	Ramp-UP Pattern
ASM-TER CH BW 16kHz	1, 2, 3, 5, 6, 7, 8, 9, 10	0.41	4	0, 0, 1, 1
VDE-TER CH BW 25kHz	11, 12, 13	0.41	8	0, 0, 1, 1, 0, 0, 1, 1
VDE-TER CH BW 50kHz	14, 15, 16	0.41	16	0, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1
VDE-TER CH BW 100kHz	17, 18, 19	0.41	32	0, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1

5.2.3.2 Training sequence [changed SP to heading 4]

The training sequence is separated in to two sections with the SAT link only using the first 14 symbols and is defined as 1111110011010100000011001010.

Table A1-2 shows the syncwords used for VDES.

TABLE A1-2

SYNCWORDS FOR VDES

Commenté [B5]: Transision from training sequence to actual data constallation (where does the rotation start?)
Jan has a proposal for the mapping wich may clarify the issue or maybe not
Action item 116

Commenté [JC6]: Confirm this is to be removed and replaced the by the new text / table from Hans document.

Usage	Symbol size	Sequence	Type	Comment
ASM-TER VDE-TER	27	1 1111100110101 0000011001010	1+ Barker13+ inverted Barker13	TC under consideration
ASM-SAT VDE-SAT	27	010001010010010000000110011	Best autocorrelation for differential detection	Based on search. Looses 0.3% of packets at E_S/N_0 of 5 dB
VDE-SAT	48	~~TBD~~000100011110011011000001010111011010110111101000		Needs to work at E_S/N_0 of -2 dB

Commenté [SPI7]: item170 VDE-SAT synch word from Hans by email

The Double Barker sequence used for ASM-TER and VDE-TER allows for detection of the 2 correlation peaks and the 13 bit known noise inbetween. Furthermore, the correlation peak size indicates frequency offset.

Commenté [SPI8]: work item 158.

5.2.3.3 Bit mapping for training sequence and signal information

For training and signal information, following mapping applies:

– 1 maps to π/4 QPSK symbol 3 (1, 1) (see Figure A1-10

– 0 maps to π/4 QPSK symbol 0 (0, 0).

For π/4 QPSK bit mapping, see § 5.2.8.

Commenté [SPI9]: Action item 68

Commenté [JC10]: Confirm ref

Commenté [SPI11]: Action item 68

Commenté [SPI12]: action item 68

5.2.3.4 Link Configuration Id [changed SP to heading 4]

The Link Configuration Id defines the channel configurations. The Link Configuration Id is used to index the table of channel configurations, see Table A1-6.

The Link Configuration Id follows the training sequence for transmissions, see Figure A1-4A and B.

The Link Configuration Id consists of 6 bits (D0, D1, D2, D3, D4, D5) encoded into a sequence of 32 bits using biorthogonal (32,6) code.

The link configuration id is not used by the SAT link.

5.2.3.5 Data with CRC-32 [changed SP to heading 4]

The data payload with its appended CRC-32 is interleaved (refer to Table A1-3), encoded (refer to § 5.2.4.1), ~~and then~~ scrambled (refer § 5.2.6) and bit mapped.

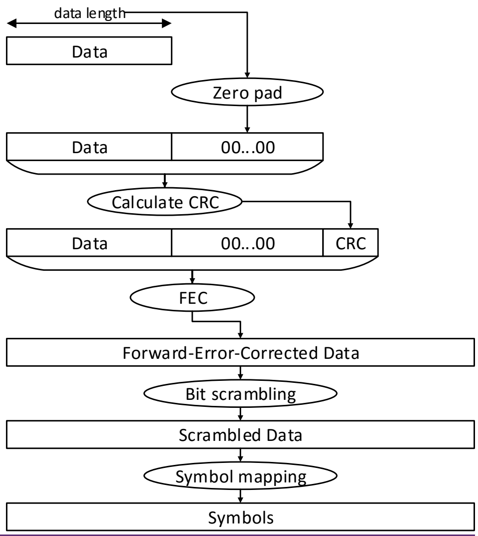
Unused payload data is zero-filled.

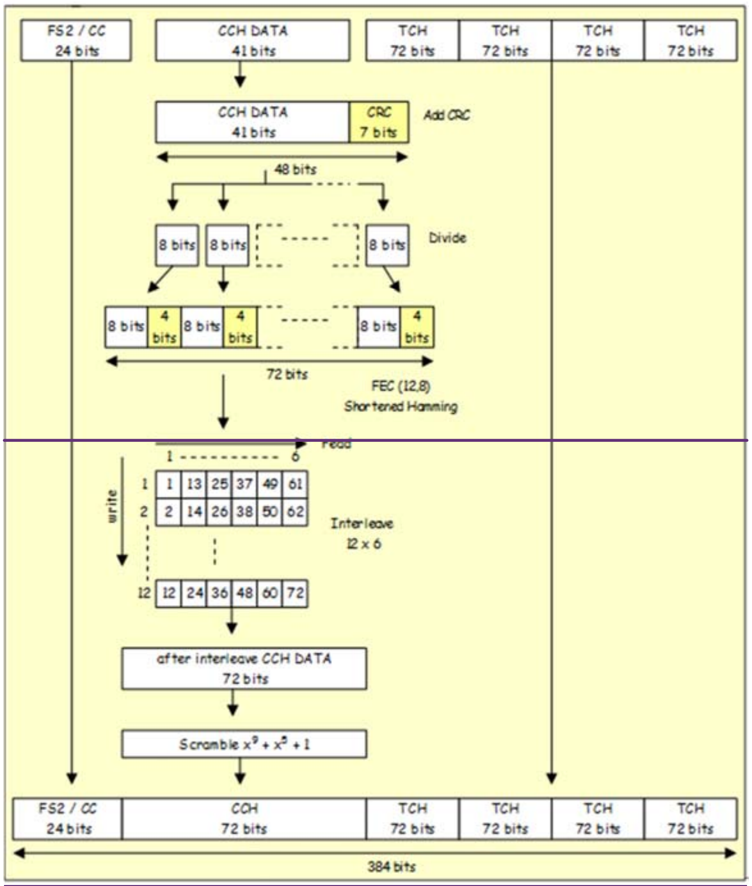
Commenté [B13]: include a flow diagram for clarity including bitorder MSB first,
Derek provides a template

Commenté [SPI14]: corrected grammatics.

FIGURE A1-6 –

Order of operations for TDMA; if CR=1 FEC is not applied





~~Needs to be VDES specific – further editing~~

5.2.3.6 Bit scrambling [changed SP to heading 4]

Scrambling of the user data is required to avoid the power spectral density to be concentrated in the narrow band. Refer to § 5.2.6 for the detailed definition of the scrambler sequence.

5.2.3.7 Guard time [changed SP to heading 4]

The guard time consists of the ramp down time from full power to −50 dBc of less than or equal to 416 µs. The remaining time is for delay and jitter.

5.2.4 Forward Error Correction [changed SP to heading 3]

5.2.4.1 Encoder Structure

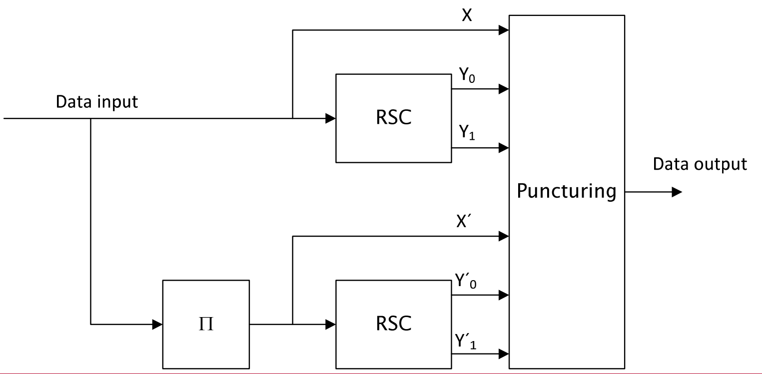
This paragraph defines the general structure of the forward error correction encoder to be used on the satellite and the terrestrial component of the VDES. The overall structure follows the specification in the ETSI EN 302 583 standard {RD-1}.

The general encoder structure is depicted in Fig. A1-7. The encoder consists of two recursive systematic convolutional (RSC) encoders concatenated in parallel. Each encoder produces 3 output bits per input bit. The first RSC encoder produces the bits X, Y_0 and Y_1, while the second encoder produces the bits X', Y'_0 and Y'_1. The <pi> block in Fig. A1-7 represents the interleaving function as described in section 5.2.4.3.

The first encoder gets as input a word **u** of k bits, with k, as specified in § 5.2.4.3. The second encoder input is denoted by **u**' and it is a permuted version of the vector **u**. The permutation is performed according to the definition provided in § 3.5.3 ~~below~~. The input **u** is the data (including padding and CRC), with MSB of each byte first. For example if the data is 0x7F, 0xA5, … **u** will be 01111111 10100101 ….

FIGURE A1-7 -

Turbo encoder structure (high-level)



Commenté [JC15]: Where is this referenced in the text?

Commenté [SP16R15]: 8 lines above.

5.2.4.2 Constituent codes [changed SP to heading 4]

The constituent codes are specified by the transfer function

$$G(D) = \begin{bmatrix} 1 & \frac{n_0(D)}{d(D)} & \frac{n_1(D)}{d(D)} \end{bmatrix}$$

where

$$n_0(D) = 1 + D + D^3$$

$$n_1(D) = 1 + D + D^2 + D^3$$

$$d(D) = 1 + D^2 + D^3.$$

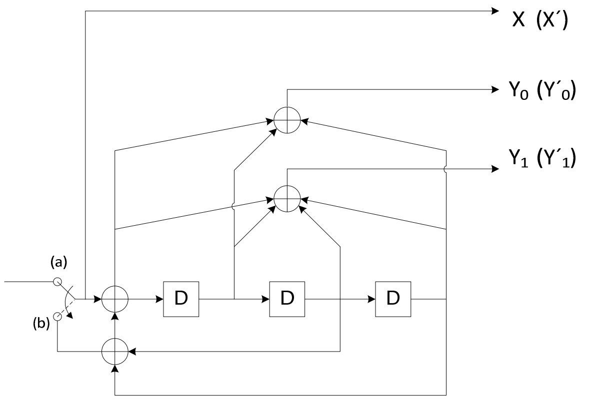
The constituted encoder definition is provided in Fig. A1-8. For the first k clocks the switch is in position (a), i.e. information is fed into the encoder. For the subsequent 6 clocks, the switch is moved to position (b) to handle the RSC trellis termination. In the first 3 termination clocks, only the RSC 1 (upper branch) is output, while in the subsequent 3 termination clocks, only the output of RSC 2 (lower branch) is provided. The termination is thus given by the sequence of 6 termination bits (X, Y_0, Y_1, X', Y'_0, Y'_1) with X output first.

FIGURE A1-8

–RSC code encoder

Commenté [JC17]: Where is this referenced in the text?

Commenté [SP18R17]: 1st line of the paragraph above: The constituded …



5.2.4.3 Interleaver definition [changed SP to heading 4]

The interleaver specification follows {RD-2}.

First factorize $k = k_1 k_2$, where the parameters k_1 and k_2 depend on the choice of the respective code, where k is the information block length. Then select prime numbers and puncturing parameters values as given in Table A1-3.

TABLE A1-3 – INTERLEAVER AND PUNCTURING PARAMETERS FOR DIFFERENT INFORMATION LENGTHS/CODE RATES

Link Conf ID	Nominal code rate	Information length	k_1 | k_2	p_1 | p_2 | p_3 | p_4 | p_5 | p_6 | p_7 | p_8	Puncturing ID	Tail ID
4	3/4	952	4|238	113|31|59|163|29|181|101|11	8	8a
5*	3/4	288	2|144	31|37|43|47|53|59|61|67	8	8
6*	3/4	672	2|336	31|37|43|47|53|59|61|67	8	8
7*	3/4	1056	2|528	31|37|43|47|53|59|61|67	8	8
8*	1/2	192	2|96	31|37|43|47|53|59|61|67	6	6
9*	1/2	448	2|224	31|37|43|47|53|59|61|67	6	6
10*	1/2	704	2|352	31|37|43|47|53|59|61|67	6	6
11	1/2	432	2|216	31|37|43|47|53|59|61|67	6	6
12	3/4	972	2|486	31|37|43|47|53|59|61|67	8	8
13	3/4	1296	2|648	31|37|43|47|53|59|61|67	8	8
14	1/2	896	2|448	31|37|43|47|53|59|61|67	6	6
15	3/4	2016	4|504	31|37|43|47|53|59|61|67	8	8
16	3/4	2688	4|672	31|37|43|47|53|59|61|67	8	8
17	1/2	1792	4|448	31|37|43|47|53|59|61|67	6	6
18	3/4	4032	4|1008	31|37|43|47|53|59|61|67	8	8

19	3/4	5376	8|672	31|37|43|47|53|59|61|67	8	8
20	1/4	96	2|48	37|83|211|61|107|101|149|167	2	2a
21	2/3	736	2|368	139|17|241| 47|109|11|29|163	7a	7a
22	2/3	3120	8|390	17|31|61|67|101|103|113|131	7a	7b
23	2/3	4544	4|1136	197|157|13|191|241|101|149|109	7a	7b
24	5/6	3788*2	4|947	83|251| 7| 47| 79| 5|227|73	9	9

*) No previous definitions or simulations results available, but a default configuration suggested.

Table A1-3 will be extended as different information block lengths are defined.

This FEC will be calculated by first choosing prime numbers p_q, $q \in (1, ..., 8)$ as given in the table A1-3.

The following operations shall be performed for $s \in (1, ..., k)$ to obtain the permutation numbers $\pi(s)$:

$$m = (s-1) \bmod 2$$

$$i = floor\ ((s-1)\ /(2k_2))$$

$$j = floor\ ((s-1)\ /2)) - ik_2$$

$$t = (19i+1) \bmod (k_1/2)$$

$$q = t \bmod 8 + 1$$

$$c = \left(p_q j + 21m\right) \bmod k_2$$

$$\pi(s) = 2(t + ck_1/2 + 1) - m$$

The permutation numbers shall be interpreted such that the s^{th} bit read out after interleaving is the $\pi(s)^{th}$ bit of the input information block.

5.2.4.4 Rate Adaptation

Rate adaptation is obtained by puncturing the encoder output as in § 5.3.1 of {RD-1}, as recalled in Table A1-4 for the first k clocks, and as in {RD-1}.

The puncturing table for the termination part is given in Table A1-5. The two last rows of Table A1-4 are not part of {RD-1}.

Commenté [JC19]: From Johnny S - This table does not relect the latest information in Table A1-6

Commenté [JC20]: Confirm ref

Commenté [JC21]: Confirm ref

TABLE A1-4 -

PUNCTURING PATTERNS FOR DATA BIT PERIODS

Punc. Pattern ID	Code Rate	Punc. Pattern (X; Y_0; Y_1; X'; Y'_0; Y'_1 | X; Y_0; Y_1; X'; Y'_0; Y'_1 | ...)
0	1/5	1;1;1;0;1;1
1	2/9	1;0;1;0;1;1 | 1;1;1;0;1;1 | 1;1;1;0;0;1 | 1;1;1;0;1;1
2	1/4	1;1;1;0;0;1 | 1;1;0;0;1;1
3	2/7	1;0;1;0;0;1 | 1;0;1;0;1;1 | 1;0;1;0;0;1 | 1;1;1;0;0;1
4	1/3	1;1;0;0;1;0
5	2/5	1;0;0;0;0;0 | 1;0;1;0;0;1 | 0;0;1;0;0;1 | 1;0;1;0;0;1 | 1;0;1;0;0;1 | 0;0;1;0;0;1 | 1;0;1;0;0;1 | 1;0;1;0;0;1 | 0;0;1;0;0;1 | 1;0;1;0;0;1 | 1;0;1;0;0;1 | 0;0;1;0;0;1
6	1/2	1;1;0;0;0;0 | 1;0;0;0;1;0
7	2/3	1;0;0;0;0;0 | 1;0;0;0;0;0 | 1;0;0;0;0;0 | 1;0;1;0;0;1
7a	2/3	1;0;0;0;0;0 | 1;0;0;0;0;0 | 1;0;0;0;0;0 | 1;1;0;0;1;0
8	3/4	1;0;1;0;0;0 | 1;0;0;0;0;0 | 1;0;0;0;0;0 | 1;0;0;0;0;0 | 1;0;0;0;0;0 | 1;0;0;0;0;1
9	5/6	1;0;0;0;0;0 | 1;1;0;0;0;0 | 1;0;0;0;1;0 | 1;0;0;0;0;0 | 1;0;0;0;0;0 | 1;0;0;0;0;0 | 1;0;0;0;0;0 | 1;0;0;0;0;0 | 1;0;0;0;0;0 | 1;0;0;0;0;0

For each rate, the puncturing table shall be read first from left to right and then from top to bottom.

Within a puncturing pattern, a '0' means that the symbol shall be deleted and a '1' means that a symbol shall be passed. A '2' or a '3' means that two or three copies of the symbol shall be passed. This is relevant for the termination periods. In particular

– For the rate 1/5 turbo code (Punct_Pat_ID=0), the tail output symbols for each of the first three tail bit periods shall be $XXXY_0Y_1$, and the tail output symbols for each of the last three tail bit periods shall be $X'X'X'Y'_0Y'_1$.

– For the rate 2/9 turbo code (Punct_Pat_ID=1), the tail output symbols for the first and the second output period shall be $XXXY_0Y_1$, for the third output period XXY_0Y_1, for the fourth and fifth output period $X'X'Y'_0Y'_1$, and for the sixth (last) output period $X'X'X'Y'_0Y'_1$.

– For the rate 1/4 turbo code (Punct_Pat_ID=2), the tail output symbols for each of the first three tail bit periods shall be XXY_0Y_1, and the tail output symbols for each of the last three tail bit periods shall be $X'X'\ Y'_0Y'_1$.

All other code rates shall be processed similar to the given examples above with the exact puncturing patterns to be derived from {RD-1}.

The puncturing table for the termination part is given in Table A1-5. The last rows of the table are introduced in this document to obtain higher rates and are not part of {RD-1}.

TABLE A1-5 - PUNCTURING AND REPETITION PATTERNS FOR TAIL BIT PERIODS (LAST 6 CLOCKS)

Punct. Pattern ID	Code Rate	Punct. / Rep. Pattern (X; Y_0; Y_1; X'; Y'_0; Y'_1 | X; Y_0; Y_1; X'; Y'_0; Y'_1 | ...)
0	1/5	3;1;1;0;0;0 | 3;1;1;0;0;0 | 3;1;1;0;0;0 | 0;0;0;3;1;1 | 0;0;0;3;1;1 | 0;0;0;3;1;1
1	2/9	3;1;1;0;0;0 | 3;1;1;0;0;0 | 2;1;1;0;0;0 | 0;0;0;2;1;1 | 0;0;0;2;1;1 | 0;0;0;3;1;1
2	1/4	2;1;1;0;0;0 | 2;1;1;0;0;0 | 2;1;1;0;0;0 | 0;0;0;2;1;1 | 0;0;0;2;1;1 | 0;0;0;2;1;1
2a	1/4	1;1;1;0;0;0 | 1;1;1;0;0;0 | 1;1;1;0;0;0 | 0;0;0;1;1;1 | 0;0;0;1;1;1 | 0;0;0;1;1;1
3	2/7	1;1;1;0;0;0 | 2;1;1;0;0;0 | 2;1;1;0;0;0 | 0;0;0;2;1;1 | 0;0;0;1;1;1 | 0;0;0;1;1;1
4	1/3	2;1;0;0;0;0 | 2;1;0;0;0;0 | 2;1;0;0;0;0 | 0;0;0;2;1;0 | 0;0;0;2;1;0 | 0;0;0;2;1;0
5	2/5	1;1;1;0;0;0 | 1;1;1;0;0;0 | 1;0;1;0;0;0 | 0;0;0;1;1;1 | 0;0;0;1;1;1 | 0;0;0;1;0;1
6	1/2	1;1;0;0;0;0 | 1;1;0;0;0;0 | 1;1;0;0;0;0 | 0;0;0;1;1;0 | 0;0;0;1;1;0 | 0;0;0;1;1;0
7	2/3	1;0;0;0;0;0 | 1;0;1;0;0;0 | 1;0;1;0;0;0 | 0;0;0;1;0;0 | 0;0;0;1;0;1 | 0;0;0;1;0;1
7a	2/3	1;1;0;0;0;0 | 1;0;0;0;0;0 | 1;0;0;0;0;0 | 0;0;0;1;1;0 | 0;0;0;1;0;0 | 0;0;0;1;0;0
7b	2/3	1;1;0;0;0;0 | 1;1;0;0;0;0 | 1;1;0;0;0;0 | 0;0;0;1;1;0 | 0;0;0;1;1;0 | 0;0;0;1;1;0
8	3/4	1;0;1;0;0;0 | 1;0;1;0;0;0 | 1;0;1;0;0;0 | 0;0;0;1;0;1 | 0;0;0;1;0;1 | 0;0;0;1;0;1
8a	3/4	1;0;1;0;0;0 | 1;0;1;0;0;0 | 1;0;1;0;0;0 | 0;0;0;1;0;1 | 0;0;0;1;0;1 | 0;0;0;1;0;0
9	5/6	1;1;0;0;0;0 | 1;0;0;0;0;0 | 1;0;0;0;0;0 | 0;0;0;1;1;0 | 0;0;0;1;0;0 | 0;0;0;1;0;0

For each rate, the puncturing table shall be read first from left to right and then from top to bottom.

5.2.5 CRC

The 32 bit ITU-T V.42 {RD-5} polynomial 0x04C11DB7 CRC is appended to the last segment of the datagram. The CRC is calculated over all fragments of the datagram datagram (including any zero padding) with MSB of each byte processed first. The resulting 32 bit CRC is appended MSB first so the receiver can verify that the result is 0x00000000 when calculated over data+padding+CRC.

$F(x) = x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^4 + x^2 + x + 1$

Initial state: 0xFFFFFFFF

5.2.6 Bit scrambling

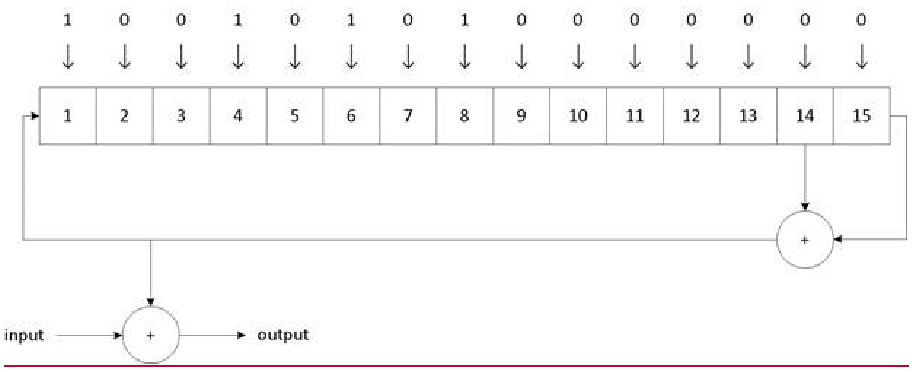
The bit scrambler shown Figure A1-9 uses the polynom:

$F(x)=1 + x^{-14} + x^{-15}$

and the initialization sequence as indicated in the top of the figure. For each new encoding block, the bit scrambler is re-initialized.

FIGURE A1-9

Bit scrambling



5.2.7 Modulation Coding Schemes [changed SP to heading 3]

~~The modulation and coding options and raw channel throughput rates are provided for a range of bandwidths and modulation and coding schemes (MCS).~~All MCS formats are defined in the Link Configuration ID Tables A1-6 to A1-9 (refer to Figures A1-4A and A1-4B. The Channel Quality Indicator (CQI) value is used by the Adaptive Coding and Modulation (ACM) mechanism.

Commenté [JC22]: Confirm deleted / replaced by new text as per Hans document

Commenté [JC23]: Confirm deleted / replaced by new text as per Hans document

Commenté [SP24R23]: Confirmed.

TABLE A1-6

.ASM Link Configuration ID parameters

PL format #	ASM-MCS-1.16-1	ASM-MCS-1.16-2	ASM-MCS-1.16-3	ASM-MCS-1.16-4	ASM-MCS-1.16-5	ASM-MCS-1.16-6	ASM-MCS-1.16-7	ASM-MCS-1.16-8	ASM-MCS-1.16-9	ASM-MCS-1.16-10	
Li nk Config ID	1	2	3	4 (SAT)	5	6	7	8	9	10	
Channel ~~bandwidth~~BW	16										kHz
Roll off filtering	0,35										
Signal ~~bandwidth~~BW	13,0										kHz
Symbol rate	9,6										ksps
Burst size	1	2	3	3	1	2	3	1	2	3	slots
Guard time	0,83			8	0,83						ms
Burst duration	25,8	52,5	79,2	72,0	25,8	52,5	79,2	25,8	52,5	79,2	ms
Symbols/ burst	248	504	760	691	248	504	760	248	504	760	symbols
Ramp-up/down	4/4										symbols
Ramp-up/down	0,41/0,41										ms
Syncword size	27										symbols
Syncword modul.	PI/4 QPSK (00/11 only)										
Link Config ID symbols	16										symbols
Link Config ID modul.	Pi/4 QPSK										
Net symbols/ burst	197	453	709	640	197	453	709	197	453	709	symbols
Channel bits	394	906	1418	1280	394	906	1418	394	906	1418	bits
Padding/ flush bits	10			11~~0~~	10						bits
FEC decoder input symbols	192	448	704	634.5~~40~~	192	448	704	192	448	704	symbols
FEC decoder input bits	384	896	1408	126~~80~~	384	896	1408	384	896	1408	bits
FEC output bits	384	896	1408	952~~60~~	288	672	1056	192	448	704	bits
FEC output bytes	48	112	176	119~~20~~	36	84	132	24	56	88	bytes
Modul.~~lati.~~	PI/4 QPSK										
Bits / symbol	2										
FEC rate	1			3/4				1/2			
E_s/N_0 on AWGN	11,0	11,0	11,0	4,5	5,3	5	4,8	3,6	3	2,8	dB
$C/(N_0+I_0)$ threshold	50,8	50,8	50,8	44,3	45,1	44,8	44,6	43,4	42,8	42,6	dBHz
Minimum CQI value	50	51	53	43	45	45	45	43	43	43	

TABLE A1-7

-VDE-TER Link Configuration ID parameters

PL format #	TER-MCS-1.25	TER-MCS-3.25	TER-MCS-5.25	TER-MCS-1.50	TER-MCS-3.50	TER-MCS-5.50	TER-MCS-1.100	TER-MCS-3.100	TER-MCS-5.100	
Link Config ID	11	12	13	14	15	16	17	18	19	
Channel BWbw	25			50			100			kHz
Roll off filtering	0,3									
Signal BWbw	25,0			49,9			99,8			kHz
Symbol rate	19,2			38,4			76,8			ksps
Burst size	1									slot
Guard time	0,83									ms
Burst duration	25,8									ms
Symbols/burst	496			992			1984			symbols
Ramp-up/down	8/8			16/16			32/32			symbols
Ramp-up/down	0.41/0.41									ms
Syncword size	27									symbols
Syncword modulation	PI/4 QPSK (00/11 only)									
Link Config ID size	16 (32,6 block code)									symbols
Link Config ID modulation	PI/4 QPSK									
Net symbols/burst	437			917			1877			symbols
Channel bits	874	1311	1748	1834	2751	3668	3754	5631	7508	bits
Padding/flush	10	15	20	42	63	84	170	255	340	bits
FEC decoder input symbols	432			896			1792			symbols
FEC decoder input bits	864	1296	1728	1792	2688	3584	3584	5376	7168	bits
FEC output bits	432	972	1296	896	2016	2688	1792	4032	5376	bits
FEC output bytes	54	122	162	112	252	336	224	504	672	bytes
Modulation	PI/4 QPSK	8PSK	16 QAM	PI/4 QPSK	8PSK	16 QAM	PI/4 QPSK	8PSK	16 QAM	
FEC rate	1/2	3/4	3/4	1/2	3/4	3/4	1/2	3/4	3/4	
E_s/N_0 on AWGN	1,0	7,9	10,2	1,0	7,9	10,2	1,0	7,9	10,2	dB
$C/(N_0+I_0)$ threshold	43,8	50,7	53,0	46,8	53,7	56,0	49,9	56,8	59,1	dBHz
Minimum CQI value	42	53	56	46	57	59	49	60	62	

TABLE A1-8

-VDE-SAT Uplink Configuration ID parameters

PL format	SAT-MCS-1.50-2	SAT-MCS-1.50-3	SAT-MCS-1.50-4	SAT-MCS-3.50-2	SAT-MCS-5.50	
Link Config ID	20	21	22	23	24**	
Channel bandwidth	50					kHz
Roll off filtering	0,25					
Signal bandwidth	42,0					kHz
CDMA chiprate	33,6					kcps
Codelength	16					chips
Symbol rate	2,1	33,6				ksps
Burst size	5	1	3			slots
Guard time	8					ms
Burst duration	125,3	18,7	72,0			ms
Symbols/burst	263	627	2419			symbols
Ramp-up/down	14/14*					symbols
Ramp-up/down	0.41/0.41					ms
Syncword size	48	27				symbols
Syncword modulation	QPSK/CDMA (00/11)	PI/4 QPSK (00/11)				
Link Configuration ID size	0	16 (32,6 block code)				symbols
Link Configuration ID modulation	NA	PI/4 QPSK				
Pilot symbol distance	17	NA		20		symbols
Total pilot symbols	121	0		1171		symbols
Net symbols/burst	201176	556	2348	227731	2277348	symbols
Channel bits	352	1112	4696	6831693	9108392	bits
Padding/flush bits	180	8	164	159	328*2	bits
FEC decoder input symbols	19276	552	23462340	22282272	23402277	symbols
FEC decoder input bits	352384	1104	46924680	66846816	93604546*2	bits
FEC output bits	8896	736	31283120	44564544	78003788*2	bits
FEC output bytes	11	92	391390	557568	975947	bytes
Modulation	QPSK/ CDMA	PI/4 QPSK		8PSK	16QAM	
FEC rate	1/4	2/3			5/6	
E_s/N_0 on AWGN	-0,9	3,9	3,9	8,0	12,2	dB
$C/(N_0+I_0)$ threshold	32,3	49,2	49,2	53,3	57,5	dBHz
Minimum CQI value	32	49	51	54	58	

*) For spread sequence it is 14/14 chips.

**) FEC block is split into two sub-blocks in order to avoid very long FEC block.

TABLE A1-9

VDE-SAT Downlink Configuration ID parameters

PL format	SAT-MCS-0.50-1	SAT-MCS-1.50-1	SAT-MCS-3.50-1	SAT-MCS-0.100	SAT-MCS-0.150	SAT-MCS-0.300	SAT-MCS-0.500	
Link Config ID	25	26	27	28	29	30	31	
Channel ~~bw~~BW	50			100	150	300	500	kHz
Roll off filtering	0,25							
Signal ~~bw~~BW	42,0			90,0	141,0	291,0	492	kHz
CDMA chiprate	33,6			72,0	112,8	232,8	393,6	kcps
Codelength	8			4				chips
Symbol rate	4,2	33,6		18,0	28,2	58,2	98,4	ksps
Burst size	90							slots
Guard time	8							ms
Burst duration	2392,0							ms
Symbols/burst	10046	80371		43056	67454	139214	235372	symbols
Ramp-up/down	14/14			30/30	47/47	97/97	163/163	symbols / chips
Ramp-up/down	0.41/0.41							ms
Syncword size	48	27		48				symbols
Syncword modulation	BPSK/ CDMA	PI/4 QPSK (00 /11)		BPSK/CDMA				
Link Config ID	16 (32,6 block code)							symbols
Link Config ID modulation	BPSK/ CDMA	PI/4 QPSK		BPSK/CDMA				
Pilot distance	20							symbols
Total pilots symbols	497	4015		2146	3364	6947	11749	symbols
Net symbols/burst	9457	80300		40786	67296	138956	234982	symbols
Channel bits	9457	160600	240900	40786	67296	138956	234982	bits
Padding/flush	1	24	4	2	0	12	22	bits
FEC decoder input symbols	9457	80300	80300	40786	67296	138956	234982	symbols
FEC decoder input bits	9456	160576	240896	40784	67296	138944	234960	bits
FEC output bits	4728	40144	120448	20392	33648	69472	117480	bits
FEC output	591	5018	15056	2549	4206	8684	14685	bytes
Modulation	BPSK/ CDMA	PI/4 QPSK	8PSK	BPSK/CDMA				
FEC rate	1/2	1/4	1/2	1/2				
E_s/N_0 on AWGN	-2,0	-2,4	5,0	-2,0				dB
$C/(N_0+I_0)$ thres	34,2	42,9	50,3	40,6	42,5	45,6	47,9	dBHz
Minimum CQI value	33	44	52	40	44	47	49	

TABLE A1-6

Modulation and coding schemes

Annex			2 ASM	3 VDE-TER	3 VDE-TER	3 VDE-TER
Channel Bandwidth (kHz)			25	25	50	100
Symbol Rate			9.6	19.2	38.4	76.8
Rolloff factor[1]			0.35	0.3	0.3	0.3
Modulation and coding scheme	Signal info	CQI	Total throughput kbit/s			
MCS-0 (π/4 QPSK, no coding)	0, 0, 0, 0	0	19.2	future	future	future
MCS-1 (π/4 QPSK, CR = 1/2)	0, 0, 0, 1	1	TBD	38.4	76.8	153.6
MCS-3 (8PSK, CR = 3/4)	0, 0, 1, 1	3	Future	57.6	115.2	230.4
MCS-5 (16QAM, CR = 3/4)	0, 1, 0, 1	5	Future	76.8	153.6	307.2

The unused MCS are reserved for future use. A maximum of 16 different MCS can be defined for each physical layer format.

5.2.8 Bit mapping

The bit mappings used throughout the Annexes are shown in figures Figs. A1-710 to A1-103.

The first output from the bit scrambler is mapped to the MSB of the first symbol, the second bit to the next bit in the symbol, and so on until the LSB of the symbol has been filled, then mapping continues in the next symbol. If more bits are needed to complete the last symbol, 0 shall be used.

Commenté [FD25]: Can this happen or do all FEC lengths results in a number of bits which all are evenly divided by 2, 3 and 4?

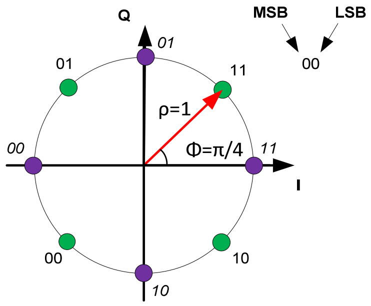
The initial state of the alternating π/4 QPSK bit mapping is defined such that the first symbol of the training sequence is mapped to the constellation defined by points $\{(1+j)/\sqrt{2}, (-1+j)/\sqrt{2}, (-1-j)/\sqrt{2}, (1-j)/\sqrt{2}\}$ (shown in green in Figs. A1-7); the next symbol is mapped to the constellation defined by points $\{1+0j, 0+j, -1+0j, 0-j\}$ (shown in purple in Figs. A1-7); and so on.

[1] The baseband shall employ a root raised cosine filter.

FIGURE A1-710

bit mapping for π/4 qpsk

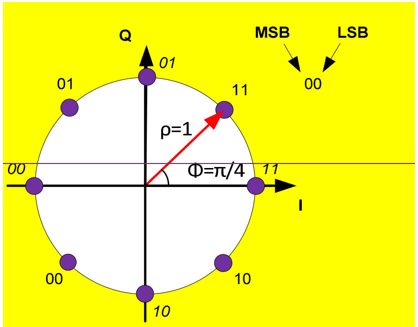
Bit Mapping for π/4 QPSK



NOTE – Odd symbols in a packet shall be selected from the constellation defined by points $(\pm 1 \pm j)/\sqrt{2}$ (shown in green); even symbols shall be selected from the constellation defined by points $\pm 1, \pm j$ (shown in purple).

FIGURE A1-7

Bit Mapping for π/4 QPSK



NOTE – Each subsequent transmission is phase-rotated by π/4.

FIGURE A1-~~8~~11

8PSK symbol to bit mapping

~~**8PSK symbol to bit mapping**~~

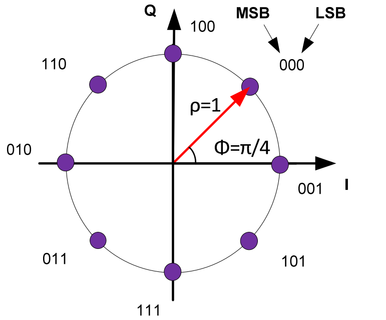


FIGURE A1-~~9~~12

Bit Mapping for 16QAM

~~**Bit Mapping for 16QAM** (MSB left, LSB right)~~

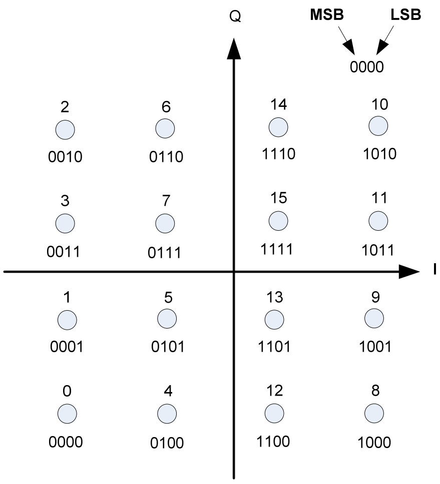
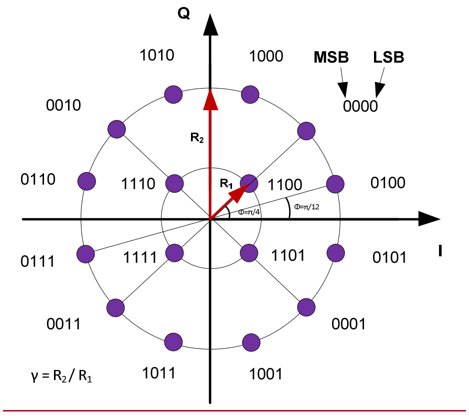


FIGURE A1-103

16APSK bit to symbol mapping

16APSK bit to symbol mapping



The 16 APSK modulation constellation is composed of two concentric rings of uniformly spaced 4 and 12 PSK points, respectively in the inner ring of radius R_1 and outer ring of radius R_2.

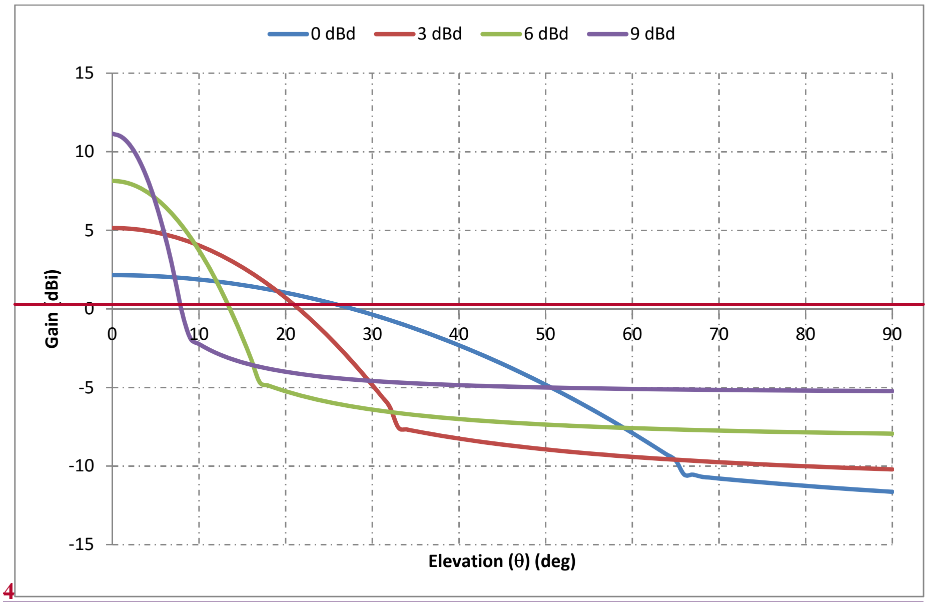
The ratio of the outer circle radius to the inner circle radius ($\gamma = R_2/R_1$) shall be equal to 3. R_1 shall be set to $1/\sqrt{7}$, R_2 shall be set to $3/\sqrt{7}$ in order to have the average signal energy equal to 1.

Similar to AIS, when data is output on the VHF data link it should be grouped in bytes of 8 bits from top to bottom of the table associated with each message in accordance with ISO/IEC 13239:2002. Each byte should be output with least significant bit first.

5.2.9 Antenna gain for VDES ship stations [changed SP to heading 3]

Existing ship antennas may be used for VDES. The maximum antenna gain for these antennas ranges from 2 dBi to 10 dBi. Representative antenna patterns are shown in Figure. A1-114.

A ship antenna with a minimum gain at 0 degrees elevation of 2 dBi at the receiver input is required.



4

5.2.10 Noise and interference level

The noise floor is a function of many sources such as vessel electronics, other radio equipment, power supplies, etc., and sensitivity is also reduced by RF cabling losses and the LNA noise figure. Table A1-10 presents representative values for the receiver noise figure.

TABLE A1-10

Ship receiver noise figure calculations

Antenna noise temperature*	245.0	K
LNA noise figure	6.0	dB
LNA noise temperature	813.8	K
Feed loss noise temp at LNA	0.0	K
Antenna noise temp at LNA	245.0	K
System noise temp at LNA	1058.8	K
System noise temp at LNA	30.2	dBK

* The galactic background antenna noise temperature is 245 K at 160 MHz {RD-4}.

5.2.11 Transmitter requirements for VDES [changed SP to heading 3]

5.2.11.1 Transmitter power

Except for Annex 2, Table A1-121 defines the requirements for VDE station transmitters.

TABLE A1-1~~2~~1

Transmitter parameters

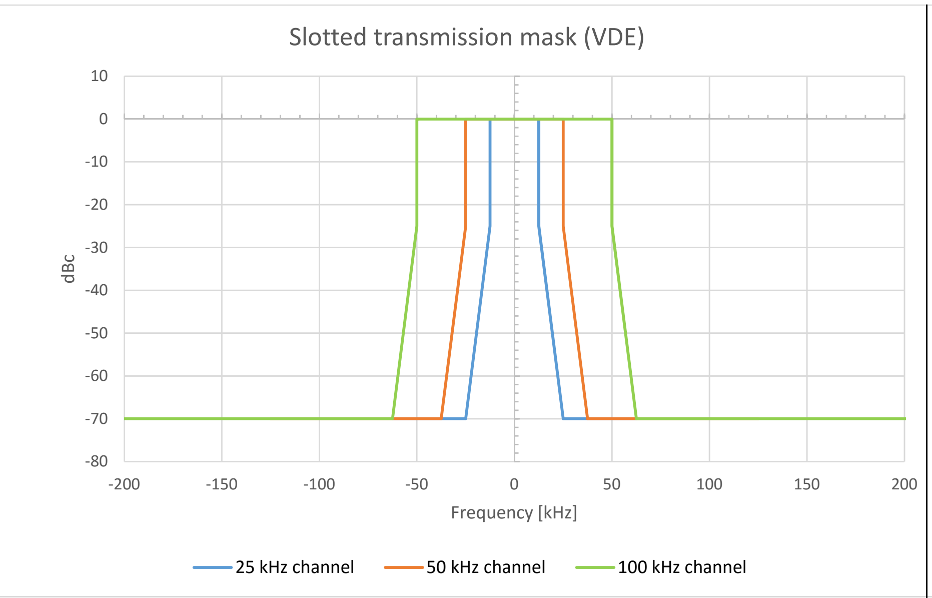
Transmitter parameters	**Requirements**	**Condition**
Frequency error	~~3~~1.5 ppm	normal
Maximum transmit power capability	For ship stations: Transmit average power should be at least 1 watt and not exceed 25 watts at the transmitter output. For shore stations: Transmit average power should be at least 12.5 watt and not exceed 50 watts at the base of the antenna. ±1.5 dB normal, +2/−6 dB extreme	Conducted
Maximum adjacent power levels for 25 kHz channel	Δ*fc* < ±12.5 kHz: 0 dBc ±12.5 kHz < Δ*fc* < ±25 kHz: below the straight line between −25 dBc at ±12.5 kHz and −70 dBc at ±25 kHz ±25 kHz < Δ*fc* < ±62.5 kHz: −70 dBc	
Maximum adjacent power levels for 50 kHz channel	Δ*fc* < ±25 kHz: 0 dBc ±25 kHz < Δ*fc* < ±37.5 kHz: below the straight line between −25 dBc at ±25 kHz and −70 dBc at ±37.5 kHz ±37.5 kHz < Δ*fc* < ±125 kHz: −70 dBc	
Maximum adjacent power levels for 100 kHz channel	Δ*fc* < ±50 kHz: 0 dBc ±50 kHz < Δ*fc* < ±62.5 kHz: below the straight line between −25 dBc at ±50 kHz and −70 dBc at ±62.5 kHz ±62.5 kHz < Δ*fc* < ±250 kHz: −70 dBc	
Spurious emissions	−36 dBm −30 dBm	9 kHz to 1 GHz 1 GHz to 4 GHz

FIGURE A1-13b Slotted transmission mask for VDE stations

Commenté [SPI26]: work item 156 closed hereby

Commenté [SP27]: Table A3-1 removed from Annex 3 to align with Annex 1.

Commenté [SP28]: Action Item#20, change proposal ChangeProposal_Item20_RN_YM_v2_20160316.docx



5.2.11.2 Ship e.i.r.p. vs. elevation angle [changed SP to heading 4]

The minimum ship e.i.r.p. vs elevation angle is shown in Table A1-1~~3~~2. There are no minimum e.i.r.p. requirements above 80 degrees elevation. Table A1-1~~3~~2 is based on a linear transmitter meeting the maximum Adjacent Channel Interference levels defined in Table A1-1~~2~~1. For saturated operation the e.i.r.p. shall be 3 dB higher.

TABLE A1-1~~3~~2

Minimum ship e.i.r.p. vs. elevation angle

Ship elevation angle	Ship antenna gain	Minimum ship e.i.r.p. with 6 W transmitter
degrees	dBi	dBW
0	3	10.8
10	3	10.8
20	2.5	10.3
30	1	8.8
40	0	7.8
50	−1.5	6.3
60	−3	4.8
70	−4	3.8
80	−10	−2.2
90	−20	−12.2

5.2.11.3 Shutdown procedure

An automatic transmitter hardware shutdown procedure and indication should be provided in case a transmitter continues to transmit for more than 2 s. This shutdown procedure should be independent of software control.

5.2.11.4 Safety precautions

The VDES installation, when operating, should not be damaged by the effects of open circuited or short circuited antenna terminals.

5.3 Link layer

This layer ensures reliable transmission of data frames between ships, ship and shore, and ship and satellite. Both connection oriented and store and forward (e.g. satellite) transfer are supported. In the case of store and forward transfer, the packet protocols are terminated at both the ship and Control Station ends.

The link layer is divided into three sub-layers with the following tasks:

5.3.1 Link management entity

Assemble ~~u~~Unique ~~w~~Word, format header, Physical Layer Frame (PL-Frame) headers, pilot tones (satellite) and VDES message bits into packets.

5.3.2 Data link services

Calculates and adds CRC check sum and completes the PL-Frame/packet.

5.3.3 Resource Management

The connection between ship and shore is normally session oriented where a Logical Channel is reserved for a particular ship either for a certain amount of data transfer or time duration.

Ship originated short messages can be sent on the Random Access Channels without resource allocation.

During heavy network loading, the network control may introduce time dispersion for resource requests or only allow traffic with high priority levels.

5.3.4 Data Structures

Data is generally transferred as packets using fixed duration Logical Channel Frames, and consist of one or multiple data packets, zero padding and a 4 byte CRC.

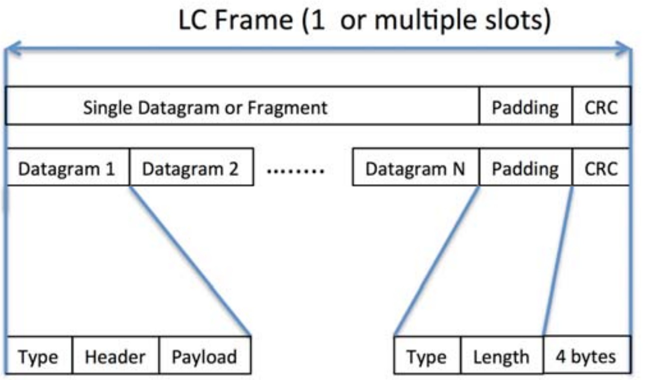
Long data packets are fragmented and sent over multiple Logical Channel frames.

The two cases are shown in figure ~~xxx1~~A1-14.

Commenté [JC29]: confirm figure reference

FIGURE A1-14

single/multiple datagram, zero padding and crc structure



~~Figure xxxx1. Single/multiple datagram, zero padding and CRC structure~~

Note that the zero padding is defined as a separate sub-packet. The 4 byte CRC is always at the end of the frame. Preamble and FEC flushing bits are not shown.

5.3.5 Adaptive Coding and Modulation/Rate Adaption [changed SP to heading 3]

The signal and interference environment is expected to change with time and location. The Control Station may measure channel quality of the received ship signal and request the ship to adjust the Modulation and Coding Scheme to maximize throughput.

Similarly, a ship will report a Channel Quality Indicator (CQI) equivalent to received C/N_0 (based on a Link Adaption Model) to the Control Station which then will adjust the Modulation and Coding Scheme to maximize throughput.

5.3.6 Signalling packets [changed SP to heading 3]

Signalling packets are used for data management and control whilst data packets are used for information transfer.

5.3.6.1 To ship signalling packets

These are used for ship paging, resource allocation and data transfer handling.

All packets contain a 1 byte packet type and a variable length header defining the length, ship ID and various other parameters.

Table ~~xxx2~~A1-13 defines the to ship signalling packets.

Commenté [JC30]: Consider rewording – signaling packets to ship

Table ~~xxx2~~A1-13

To ship signalling packets

Media Access Control				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	000	1	Type	
2	0 to 2^{16}-1	2	Length	6: Total packet size in bytes, fixed at 6 bytes
3	0-255	1	Media Access priority level	0: All accesses allowed 1: High priority only 2: Medium priority 3: Low priority 255: No accesses allowed
4	0-255	1	Random Access spreading interval	Randomly selected from RA Logical Channel group, randomly selected within LC group
5	0-255	1	System status	0: Normal 10: Busy 20: Temporally out of service 30: Scheduled out of service
To ship Announcement/Paging				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	001 or 002	1	Type	001: Paging a specific ship for in-coming datagram 002: Paging a specific ship for mobility management update
2	0 to 2^{16}-1	2	Length	Total packet size in bytes, variable
3		4	Source ID	Source of the request
4	0 to 2^{32}-1	4	Ship ID #1	
	………			
Last	0 to 2^{32}-1	4	Ship ID #N	
Multicast resource allocation announcement				

Commenté [A31]: Source of the request needs to be added into all tables
Gillian please

Commenté [JC32R31]: Not quite sure I know what you mean by source of request to be added to tables?

Field no	Value (Dec)	Size (Bytes)	Function	Content
1	003	1	Type	
2	0 to 2^{16}-1	2	Length	Total size in bytes, variable
3	0-255	1	Type of multicast	1: Group multicast 2: Area multicast
4	0-255	1	Logical Channel no	
5	0-255	1	Session ID	To support multiple sessions within a logical channel
6	0 to 2^{32}-1	4	Datagram size in bytes	

Unicast to ship resource allocation announcement

Field no	Value (Dec)	Size (Bytes)	Function	Content
1	004	1	Type	
2	0 to 2^{16}-1	2	Length	Total size in bytes, variable
3	0 to 2^{32}-1	4	Ship ID #1	
4	0-255	1	Logical Channel no	
5	0-255	1	Session ID	Multi session support
6	0-255	1	ACK Logical Channel	
7	0-255	1	ACK LC Subchannel	Set to 0 if not used
8	0-255	1	CQI	
	………			
	0 to 2^{32}-1	4	Ship ID #N	
	0-255	1	Logical Channel	
	0-255	1	Session ID	
	0 to 2^{32}-1	4	Datagram size in bytes	
	0-255	1	ACK Logical Channel	
	0-255	1	CQI	
Last	0-255	1	ACK LC Subchannel	

Unicast resource allocation announcement to ship originated requests

Field no	Value (Dec)	Size (Bytes)	Function	Content
1	005	1	Type	
2	0 to 2^{16}-1	2	Length	Total size in bytes, variable
3	0 to 2^{32}-1	4	Ship ID #1	
4	0-255	1	Logical Channel no	
5	0-255	1	Session ID	Multi stream support
6	0-255	1	Logical Channel Subchannel	0: When full LC frame is allocated, 1-255 indicates the logical subframe number that will be used
7	0-255	1	CQI	
	………			
	0 to 2^{32}-1	4	Ship ID #N	
	0-255	1	Logical Channel	
	0-255	1	Session ID	Multi stream support

	0-255	1	CQI	
Last	0-255	1	Logical Channel Subchannel	
To ship Access Denied/Resource de-allocation				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	006	1	Type	This can be used both at system access and during a given session
2	0 to 2^{16}-1	2	Length	Total size in bytes, variable
3	0 to 2^{32}-1	4	Ship ID #1	
4	0-255	1	Reason for Reject/Clear	0: Unrecognised ship ID 1: Unrecognised packet 2: Access denied by operator 3: Protocol error 4: System reset 5: All sessions cleared 6: Cleared for high priority traffic 7: Timeout 8: Shore address not recognised 9: Requested service not supported 10: Ship requested de-allocation 11: Called ship not reachable
	………			
	0 to 2^{32}-1	4	Ship ID #N	
	0-255	1	Session ID	
Last	0-255	1	Reason for Reject/Clear	
Control station ACK/ACM				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	007	1	Type	
2	0 to 2^{16}-1	2	Length	Total size in bytes, variable
3	0 to 2^{32}-1	4	Ship ID #1	
4	0-255	1	Session ID	
5	0-255	1	ACM or EDN	0: Maintain MCS 1: Increment MCS (higher rate) 2: Decrease MCS 3: End Delivery Notification
6	0 to 2^{16}-1	2	ACK/NACK mask	Relevant bit set for failed fragments 1 to 16
7	0-255	1	CQI	
8	0-255	1	Power setting	0: Maintain Power Level 1: Increase Power Level 2: Decrease Power Level
	………			
	0 to 2^{32}-1	4	Ship ID #N	
	0-255	1	Session ID	
	0-255	1	ACM or EDN	0: Maintain MCS 1: Increment MCS (higher rate) 2: Decrease MCS 3: End Delivery Notification
	0-255	1	CQI	

Commenté [A33]: Repeat 7/8 at the end of this message

	0-255	1	Power setting	0: Maintain Power Level 1: Increase Power Level 2: Decrease Power Level
Last	0 to 2^{16}-1	2	NACK mask	Relevant bit set for failed fragments 1 to 16

5.3.6.2 From ship signalling packets

These are used for ship resource request and data transfer handling. A special very short (11 byte) packet is used for unusual interference conditions and uses a 16 bit CRC.

Table ~~xxx3~~ A1-14 defines the from ship signalling packets.

Table A1-14~~xxx3~~.

From ship signalling packets

Ship response to Announcement/Paging				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	010	1	Type	
2	0 to 2^{16}-1	2	Length	Fixed, 12 bytes
3	0 to 2^{32}-1	4	Ship ID	
4	0-255	1	Session ID	
5	0 to 2^{32}-1	4	Terminal capabilities	Update to reflect mask values
6	0 to 2^{24}-1	3	Coarse latitude, +/- 90 degrees N, 2s complement 1/10th minute resolution, relative the service area NW corner	
7	0 to 2^{24}-1	3	Coarse longitude, +/- 180 degrees E, 2s complement, 1/10th minute resolution relative to the service area SE corner	
8	0-255	1	CQI	Received C/N_0 in dBHz

Commenté [JC34]: Consider rewording 'signalling packetst from ship'

Commenté [A35]: Should be a mask defining capabilities

Commenté [A36]: Use the definition from Annex 2 (1371)

Commenté [A37]: Same as above

Very short response to Announcement (11 bytes) – satellite only				
Field no	Value (Dec)	Size (Bytes)	Function	Content
1	011	1	Type	
2	0 to 232-1	4	Ship ID	
3	0-255	1	Session ID	
4	0-255	1	Terminal capabilities	1: Compliant 2092-1 2: Compliant 2092-2
5	0 to 216-1	2	CRC-2	16 bit CRC used

Ship resource request				
Field no	Value (Dec)	Size (Bytes)	Function	
1	012	1	Type	
2	0 to 2^{16}-1	2	Length	
3	0 to 2^{32}-1	4	Source ID	
4	0-255	1	Session ID	
5	0 to 2^{32}-1	4	Destination ID	
6	0 to 2^{32}-1	4	Terminal capabilities	mask
7	0 to 2^{32}-1	4	Datagram size in bytes	
8	0-255	1	CQI	Received C/N0 in dBHz
9	0-255	1	Priority	0 Default
10	0-255	1	Communications mode	0: Default 1: Direct ship to ship mode

Ship ACK/ACM				
Field no	Value (Dec)	Size (Bytes)	Function	Content
1	013	1	Type	
2	0 to 2^{16}-1	2	Length	
3	0 to 2^{32}-1	4	Ship ID	
4	0-255	1	Session ID	
5	0 to 2^{16}-1	2	ACK/NACK mask	Relevant bit set for failed fragments 1 to 16
6	0-255	1	CQI	Received C/N_0 in dBHz
7	0-255	1	ACM or EDN	0: Maintain MCS 1: Increment MCS (higher rate) 2: Decrease MCS 3: End Delivery Notification
8	0-255	1	Power setting	0: Maintain Power Level 1: Increase Power Level 2: Decrease Power Level

Very short ACK/ACM (11 bytes) – satellite only				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	014	1	Type	
2	0 to 2^{32}-1	4	Ship ID	
3	0-255	1	Session ID	
4	0 to 2^{16}-1	2	ACK/NACK mask	Relevant bit set for failed fragments 1 to 16
5	0-255	1	CQI	Received C/N_0 in dBHz
6	0 to 2^{16}-1	2	CRC-2	16 bit CRC used

Ship de-allocation request				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	015	1	Type	Release the allocated resources
2	0 to 2^{16}-1	2	Length	
3	0 to 2^{32}-1	4	Ship ID	
4	0-255	1	Session ID	Session ID 0 clear all ship connections
5	0-255	1	Reason for de-allocation	1: Time-out, 2: Retry limit exceeded 3. End of session

Very short ship clear session (11 bytes) – satellite only				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	016	1	Type	
2	0 to 2^{32}-1	4	Ship ID	
3	0-255	1	Session ID	
5	0-255	1	Reason for disconnection	1: Time-out, 2: Retry limit exceeded
6	0 to 2^{16}-1	2	CRC-2	16 bit CRC used

5.3.6.3 Ship to ship signalling

These are used to set up connections with other ships in the area. RATDMA is used to select a Logical Channel for the data transfer. All signalling takes place on Logical Channel 0 defined on the Bulletin Board.

Table ~~xxxx~~4A1-15 shows the signalling packet content.

Table A1-15~~xx.4~~

Ship to ship signalling outside Control Station service area

Ship paging ship				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	90	1	Type	
2	0 to 2^{16}-1	2	Length	Total packet size in bytes, variable
3	0 to 2^{32}-1	4	Source Ship ID #	
4	0-255	1	Priority	Default 0
5	0 to 2^{32}-1	4	Destination Ship ID #	
6	0 to 2^{32}-1	4	Terminal capabilities	

Ship response to Paging				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	
1	091	1	Type	
2	0 to 2^{16}-1	2	Length	
3	0 to 2^{32}-1	4	Ship ID	
4	0-255	1	Session ID	
5	0 to 2^{32}-1	4	Terminal capabilities	
6	0 to 2^{24}-1	3	Coarse latitude, +/- 90 degrees N, 2s complement 1/10th minute resolution, relative the service area NW corner	
7	0 to 2^{24}-1	3	Coarse longitude, +/- 180 degrees E, 2s complement, 1/10th minute resolution relative to the service area SE corner	
8	0-255	1	CQI	Received C/N_0 in dBHz
9	0-255	1	Logical Channel no	
10	0-255	1	Session ID	Multi stream support
11	0-255	1	Logical Channel Subchannel	0: When full LC frame is allocated

Commenté [A38]: Use the definition from Annex 2 (1371)

Commenté [A39]: Same as above

Ship to ship short message				
Field no	Value (DEC)	Size (bytes)	Function	Comment
1	92	1	Type	
2	2^{16}-1	2	Length	
3	2^{32}-1	4	Originating ship ID	
4	2^{8}-1	1	Session ID	
5	2^{32}-1	4	Destination ship ID	

6	2^8-1	1	Retransmission no	Handles lost ACKs
7		Variable	Payload	
Ship to ship short message ACK				
Field no	Value (DEC)	Size (bytes)	Function	Comment
1	92	1	Type	
2	2^{16}-1	2	Length	
3	2^{32}-1	4	Originating ship ID	
4	2^8-1	1	Session ID	
5	2^{32}-1	4	Destination ship ID	
6	2^8-1	1	ACK/NACK/Reject	0: ACK 1: NACK 3: Communications refused

5.3.7 Data transfer packets

[text to introduce section]

5.3.7.1 Shore originated data

Multicast data is transmitted on a shared Logical Channel, whilst Unicast date can be either time multiplexed or carried on an allocated LC.

Several short datagrams that fit within a LCF Frame are sent sequentially. Zero padding packets are added at the end to fill the LCF.

Large datagrams that exceeds the capacity of a Logical Channel Frame is transferred as multiple fragments. Each fragment is sequencely numbered 0 to 15, and a 2 byte bit map is used to request retransmission of one or multiple fragments. Datagrams with more than 15 fragments use modulo 15 numbering.

The packet types are defined in Table ~~xxx5x~~A1-16.

Commenté [JC40]: Text to introduce section

Commenté [JC41]: Consider rewording – 'each fragment is numbered in sequnce' or 'each fragment in sequentially numbered'

Table ~~xx5x.~~A1-16

To ship data packet types

Bulletin Board datagram				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	020	1	Type	
2	0 to 2^{16}-1	2	Length	Total size in bytes, variable
3		Variable	Payload	Bulletin Board fixed fields
Zero padding variable length				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	021	1	Type	
2	0-255	1	Length	Total number of zero bytes
Zero padding single byte				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	022	1	Type	1 byte zero padding
Group Multicast start datagram				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	023	1	Type	
2	0 to 2^{16}-1	2	Length	Total size in bytes, variable
3	0 to 2^{32}-1	4	Destination	Group ID
4	0 to 2^{16}-1	2	Number of fragments	
5		Variable	Payload	Multicast content
Area Multicast start datagram				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	024	1	Type	
2	0 to 2^{16}-1	2	Length	Total size in bytes, variable
3		3	Coarse latitude, +/- 90 degrees N, 2s complement 1/10th minute resolution, relative the service area NW corner	AIS format
4		3	Coarse longitude, +/- 180 degrees E, 2s complement, 1/10th minute resolution relative to the service area SE corne	AIS format
5	0 to 2^{16}-1	2	Number of fragments	
6		Variable	Payload	Multicast content

Commenté [A42]: Use the definition from Annex 2 (1371)

Commenté [A43]: Same as above

Network operator text message to all ships				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	025	1	Type	
2	0 to 2^{16}-1	2	Length	Total size in bytes, variable
3		Variable	Payload	ASCII text message
Network operator binary message to all ships				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	029	1	Type	
2	0 to 2^{16}-1	2	Length	Total size in bytes, variable
3		Variable	Payload: Data format to be defined in the payload	Binary
To ship Start Fragment/Single Fragment				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	026	1	Type	
2	0 to 2^{16}-1	2	Length	Total size in bytes, variable
3	0 to 2^{16}-1	2	Number of fragments; for single fragment message / short message: number of fragments = 1	
4	0 to 2^{32}-1	4	Ship ID	
5	0-255	1	Session ID	
6		Variable	Payload	
To ship Continuation Fragment				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	027	1	Type	
2	0 to 2^{16}-1	2	Length	Total size in bytes, variable
3	0 to 2^{32}-1	4	Ship ID	0: For multicast
4	0-255	1	Session ID	
5	0-255	1	Fragment no	
6		Variable	Payload	

To ship End Fragment				
Field no	Value (Dec)	Size (Bytes)	Function	Content
1	028	1	Type	
2	0 to 2^{16}-1	2	Length	Total size in bytes, variable
3	0 to 2^{32}-1	4	Ship ID	
4	0-255	1	Session ID	
5	0-255	1	Fragment no	Modulo 15, 1 to 15.
6		Variable	Payload	

To ship short unicast message				
Field no	Value (Dec)	Size (Bytes)	Function	Content
1	30	1	Type	
2	0 to 2^{16}-1	2	Length	Total size in bytes, variable
4	0 to 2^{32}-1	4	Ship ID	
5	0-255	1	Session ID	
6		Variable	Payload	

5.3.7.~~1~~2 Fron ship data transfer

Commenté [JC44]: Consider rewording – data transfer from ship

These packet formats are similar to the shore originated formats and given in Table ~~xxxx6~~A1-17. Short messages can be transferred using the Random Access signalling channel. The very short (11 byte) packet is used for unusual interference conditions and uses a 16 bit CRC and predefined terrestrial addressing.

Table ~~xxxx.6~~A1-17

From ship Data packet formats

Short RA message from ship (with ACK)				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	040	1	Type	
2	0 to 2^{16}-1	2	Length	
3	0 to 2^{32}-1	4	Ship ID	
4	0-255	1	Session ID	
5	0-255	1	CQI	Received C/N_0 in dBHz
6		4	Destination	
7		Variable	Payload	
Very short RA message from ship (11 bytes, with ACK) – satellite only				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	041-056	1	Type	16 types of content/
2	0 to 2^{32}-1	4	Ship ID	
3	0-255	1	Destination	Preset IPv 6 list
4		3	Payload	
5	0 to 2^{16}-1	2	CRC-2	16 bit CRC used
Short RA message from ship (without ACK)				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	057	1	Type	
2	0 to 2^{16}-1	2	Length	
3	0 to 2^{32}-1	4	Ship ID	
4	0-255	1	Session ID	
5		4	Destination ID	6
6		Variable	Payload	

Very short RA message from ship (11 bytes, without ACK) – satellite only				
Field no	Value (Dec)	Size (Bytes)	Function	Content
1	058-073	1	Type	16 types of content
2	0 to 2^{32}-1	4	Ship ID	
3	0-255	1	Destination	Preset IPv 6 list
4		3	Payload	
5	0 to 2^{16}-1	2	CRC-2	16 bit CRC used

From ship Start Fragment/Single Fragment				
Field no	Value (Dec)	Size (Bytes)	Function	Content
1	074	1	Type	
2	0 to 2^{16}-1	2	Length	Total size in bytes, variable
3	0 to 2^{16}-1	2	Number of fragments / short message: number of fragments = 1	
4	0 to 2^{32}-1	4	Ship ID	
5	0-255	1	Session ID	
6		4	Destination ID	
7		Variable	Payload	

From ship Continuation Fragment				
Field no	Value (Dec)	Size (Bytes)	Function	Content
1	075	1	Type	
2	0 to 2^{16}-1	2	Length	Total size in bytes, variable
3	0 to 2^{32}-1	4	Ship ID	
4	0-255	1	Session ID	
5	0-255	1	Fragment no	
6		Variable	Payload	

From ship End Fragment				
Field no	Value (Dec)	Size (Bytes)	Function	Content
1	076	1	Type	
2	0 to 2^{16}-1	2	Length	Total size in bytes, variable
3	0 to 2^{32}-1	4	Ship ID	
4	0-255	1	Session ID	
5	0-255	1	Fragment no	
6		Variable	Payload	

Zero Padding Variable length				
Field no	Value (Dec)	Size (Bytes)	Function	Content
1	080	1	Type	
2	0-255	1	Length	Total number of zero bytes

Zero Padding Single byte				
Field no	Value (Dec)	Size (Bytes)	Function	Content
1	081	1	Type	1 byte zero padding

5.3.38 Media Access Control

Provides methods for granting data transfer access.

Commenté [JC45]: What happens to the existing 5.3 (remaining). Next comments is on 5.4 – Network Layer. This includes new text added during intersessional.

5.3.49 Data encapsulation

The data segments of each PL-Frame contain multiple variable length encapsulated datagrams. Each datagram contains the following encapsulation fields:

– Datagram type (1 byte)
– Datagram size (3 bytes)
– Ship ID (4 bytes)
– Transaction ID (4 bytes, optional)
– Datagram sequence number (2 bytes, for multisegment datagrams)
– Source ID (8 bytes, optional)
– Datagram payload (variable)
– Data padding (variable, less than 8 bits)
– CRC (4 bytes).

5.3.510 Cyclic redundancy check

Refer to § 3.6.

Commenté [JC46]: Is this required then?

5.3.611 Automatic repeat request (ARQ)

Datagrams may or may not use ARQ, this is defined for each datagram type. An ARQ will request selective retransmission of a specific lost datagram segment.

5.3.712 Acknowledgement (ACK)

All datagrams without CRC errors are acknowledged over the satellite link.

5.3.813 End delivery notification (EDN)

All datagrams successfully delivered to the destination will be notified to the source.

5.3.914 End delivery failure (EDF)

All datagrams not successfully delivered within the timeout or retry limit will be notified to the source.

5.3.1~~0~~5 Physical and logical channels [changed SP to heading 3]

VDES will operate under a wide range of conditions that vary with location and time. The capacity mix used for to/from ship signalling and data channels can therefore be reconfigured over the air to optimise performance. A network can use up to 13 Logical Channels (LC) each using a configurable number of timeslots at a particular frequency, a default Link Configuration ID (PL format) and a defined function (data/signalling) .

VDE-TER uses 7 configurable Logical Channels for signalling and 5 permanently allocated to user data.

VDE-SAT uses 12 Logical Channels for signalling and data.

Logical Channels are used in signalling and for resource allocations and use a 4 bit field.

The Logical Channel Position uses a 7 bit field.

~~[Content to be provided by Krzyzstof and Hans]~~

5.3.1~~0~~5.1 Physical channels

The Physical channels parameters are defined in Tables xxx. The channels can be 13 (ASM), 25, 50, 100, 150, 300 or 500 kHz wide. Adaptive Coding and Modulation (ACM) functionality is supported when CQI information is provided on the links.

ASM is defined as Random Access Channels using SOTDMA and ACK from a Control Station is sent on the general ASC. The ASM reception flag on the Bulletin Board is set when this functionality is provided. The ASM uplink frequencies are given in Table 3.

~~[Content to be provided by Krzyzstof and Hans]~~

5.3.1~~0~~5.2 Logical channels

A LC is defined by the following parameters:

- Logical Channel number (0-12 for 1/2 frequencies, 0-36 for 3/6 frequencies)
- Logical Channel Position (Satellite uplink only, 0-90)
- Function (Random Access, Announcement, Ship originated data, Ship terminated data and Bulletin Board)
- VDE-SAT may use combined functions (Bulletin Board + Assignments, Assignments+ Downlink Data)
- Centre frequency (up to 6)
- Size in slots (0, 1, 2, 3, 5, 30, 90 or 180 slots)
- Default Link Configuration ID (0-63)

The LCs are defined on a Bulletin Board retransmitted every minute starting at slot 0. LC 0 defines the Bulletin Board.

The VDE-TER lowest frequency starts with LC 0. The next frequency starts with LC13. VDE-SAT LCs starts with the highest frequency.

The Terrestrial Bulletin Board is transmitted on the lowest frequency only and the Satellite Bulletin Board on the highest frequency only.

~~[Content to be provided by Krzyzstof and Hans]~~

5.3.105.2.1 Signalling logical channels

The following to ship signalling LC functionality/content is defined:

- Bulletin Board (Network ID, network configuration, system information, network operator message)
- Announcement channel (Bulletin Board version, ship paging, resource allocation (LC)/ LC Position no/access reject reason, uplink minimum access priority level, random access randomizing channels, random access retry interval, received CQI, ACK/selective NACK, Message ACK, connection disconnect/reason, End Delivery Notifications)

The following from ship signalling LC functionality/content is defined:

- Random Access Data (short message, CQI, ACK supported flag)
- Random Access Resource request (priority level, CQI, datagram size, retry count)
- Random Access ACK (message ID, CQI, ACK/selective NACK, End Delivery Notification)

Assigned Signalling (message ID, CQI, ACK/selective NACK, End Delivery Notification)

[Content to be provided by Krzyzstof and Hans]

5.3.10.2.2 Bulletin board signalling channel

[Content to be provided by Krzyzstof and Hans]

5.3.10.2.3 Announcement signalling channel (ASC)

[Content to be provided by Krzyzstof and Hans]

5.3.10.2.4 Multicast data channel (MDC)

[Content to be provided by Krzyzstof and Hans]

5.3.10.2.5 Unicast data channel (UDC)

[Content to be provided by Krzyzstof and Hans]

5.3.105.3 Bulletin Board

The Bulletin Board content is defined in table [1].Table A1-18

~~Table [1].~~Table A1-18

VDES Bulletin Board construction (fixed fields)

Name	Description	Total size (bytes)	Comment
Network (area of applicability) ID	The ID/type of the Network	4	The first 2 bits (MSB) define the Bulletin Board type. 00 is used for ship to shore 01 is used for shore to ship 10 is used for ship to ship 11 is used for satellite The remaining 30 bits are used to uniquely address up to 1.07 10^9 networks
Control Station ID	The Station number within a Network	1	
Bulletin Board version	Version number of this Bulletin Board	2	All valid versions are stored in the ship terminal (includes Configuration Message)
Validity of this version	Lifetime of this version in number of 1 minute frames	2	Up to 45 days
Logical Channel definitions	Logical Channel, ~~MODCOD~~Link Configuration ID, slot size, function	TER: 42 SAT: 72	See ~~Table~~TABLE A1-15, A1-16, A1-17~~-2~~ Up to 37 Logical Channels using 6 frequencies defined. Additional Logical Channels can be defined in a Configuration Message ~~(Table 3~~, see TABLE A1-19~~)~~
Modulation, coding and protocol versions supported	Discrete combinations	1	Defines a mandatory base set and optional more capable versions. Network ID segmentation could be used to distinguish different network types. ASM reception flag one of the parameters for satellite.
Service Area Point 1	Packet defining the Service Area North ~~West~~East corner	7	~~GPS~~GNSS ~~coordinates~~rectangle ~~in AIS format. A rectangle is formed~~ as defined in Recommondation ITU-R M.1371~~AIS. (TBC)~~
Service Area Point 2	Packet defining the Service Area South ~~East~~West corner	7	~~GPS coordinates in AIS format~~
System Configuration Message	Logical Channel number for the Configuration Message containing additional parameters/data	1	Used for additional data/information that does not fit within a standard Bulletin Board. Defined in Table 5. Set to 0 when not used.
Expansion	Future use	9	
Authentication and integrity sequence		32	Optional. Filled with zeros if not used.
Padding		0	TBD
	Fixed field size	108/139=8	TER/SAT Bytes

The relationship between LC and Physical Layer for Ship to shore, Shore to ship, Ship to Ship and Satellite to/from Ship mappings are shown in ~~[~~Figures A1-15, A1-16, A1-17, and A1-18 [A, B, C and D].

5.3.1~~0~~5.3.1 VDE-TER Default slot to LC mapping

VDE-TER uses hex slot numbering and all signalling takes place in Hex slot 0. There are TDMA 5 user data channels, each use exclusively one Hex slot (1 to 5). The 5 User Data Channels corresponds to Logical Channels 8 to 12. Each data channel has a dedicated Assignment Channel used for signalling (ASC1 to ASC5).

The function, default Link Configuration ID and number of slots for Logical Channels 0 to 6 are set by the Control Station, and repeated until the end of the frame is reached. (slot 2249). The Control Station can optimise the capacity used for random access and signalling based on traffic loading. Logical Channel 7 is not used in VDE-TER and has a size of 0 slots.

FIGURE A1-15

VDE-TER Ship to shore default slot to LC mapping (lower leg)

Logical channel	1					2	3	4	5	6		6	Logical channel
0	RACH					ASC1	ASC2	ASC3	ASC4	ASC5	....	ASC5	
1	User Data Channel 1 (UDCH1) associated with ASC1										....		8
2	User Data Channel 2 (UDCH2) associated with ASC2										....		9
3	User Data Channel 3 (UDCH3) associated with ASC3										....		10
4	User Data Channel 4 (UDCH4) associated with ASC4										....		11
5	User Data Channel 5 (UDCH5) associated with ASC5										....		12
TDMA channel number	0	1	2	3	4	5	6	7	8	9		374	Logical channel
	Hex slot												

FIGURE A1-16-B

VDE-TER Shore to ship default slot to LC mapping (upper leg)

Logical channel	0					1	2	3	4	5	6		5	Logical channel
0	TBB					ASC 1	ASC 2	ASC 3	ASC 4	ASC 5	RACH	....	ASC 5	
1	User Data Channel 1 (UDCH1) associated with ASC1											....		8
2	User Data Channel 2 (UDCH2) associated with ASC2											....		9
3	User Data Channel 3 (UDCH3) associated with ASC3											....		10
4	User Data Channel 4 (UDCH4) associated with ASC4											....		11
5	User Data Channel 5 (UDCH5) associated with ASC5											....		12
TDMA channel number	0	1	2	3	4	5	6	7	8	9	10		374	Logical channel
	Hex slot													

By monitoring the Terrestrial Bulletin Board, ships will determine if they are within a Control Station service area and not initiate ship-to-ship transmissions when interference to ship to shore communications is likely.

FIGURE A1-17-C

VDE-TER Ship to ship default slot to LC mapping (upper leg)

Logical channel	0					1	2	3	4		5	6		5	Logical channel
0	TBB					ASC 1	ASC 2	ASC 3	ASC 4		ASC 5	RACH	....	ASC 5	
1		User Data Channel 1 (UDCH1) associated with ASC1											....		8
2		User Data Channel 2 (UDCH2) associated with ASC2											....		9
3		User Data Channel 3 (UDCH3) associated with ASC3											....		10
4		User Data Channel 4 (UDCH4) associated with ASC4											....		11

Commenté [JC47]: Note – all tables are as per the original – the colour appears to be missing due to track changes. View in 'final' or 'no changes'

5		User Data Channel 5 (UDCH5) associated with ASC5										....			12
TDMA channel number	0	1	2	3	4	5	6	7	8		9	10		374	Logical channel
		Hex slot													

5.3.105.3.2 VDE-SAT default Bulletin Board

Hex slot numbering is not used by VDE-SAT because physical layer formats with length 1, 3, 5 are used on uplink and 90 slots is used for downlink. Global slot numbering from 0 to 2249 is used.

Figure D shows the default half-duplex satellite LC channel mapping.

FIGURE A1-18~~D –~~

VDE-SAT half duplex default slot to LC mapping (upper and lower leg)

	SBB+ ASC	ASC+ Data Down	Data Down 1	Data Down 2	Data Down 3	Data Down 4	Data Up 1	Data Up 2	Data Up 3	Data Up 4	Data Up 5	Data Up 6	RACH
Global start slot	0	90	180	270	360	450	540	570	600	630	660	690	720
Size in slots	90	90	90	90	90	90	30	30	30	30	30	30	90
Logical channel	0	1	2	3	4	5	6	7	8	9	10	11	12

Repeat 1		ASC+ Data Down	Data Down 1	Data Down 2	Data Down 3	Data Down 4	Data Up 1	Data Up 2	Data Up 3	Data Up 4	Data Up 5	Data Up 6	RACH
Global start slot		810	900	990	1080	1170	1260	1290	1320	1350	1380	1410	1440
Size in slots		90	90	90	90	90	30	30	30	30	30	30	90
Logical channel		1	2	3	4	5	6	7	8	9	10	11	12

Repeat 2		ASC+ Data Down	Data Down 1	Data Down 2	Data Down 3	Data Down 4	Data Up 1	Data Up 2	Data Up 3	Data Up 4	Data Up 5	Data Up 6	RACH
Global start slot		1530	1620	1710	1800	1890	1980	2010	2040	2070	2100	2130	2160
Size in slots		90	90	90	90	90	30	30	30	30	30	30	90
Logical Channel		1	2	3	4	5	6	7	8	9	10	11	12

Downlink slots are transmitted by the satellite 2 ms before UTC epoch, and uplink slots are received 2 to 10 ms after UTC epoch. This could cause the satellite to 4 to 12 ms of a packet when switching from receive to transmit. The last receive slot before a transmit slot is therefore not used. For the default configuration the last RACH slot is not used.

The VDE-SAT and ASM-SAT uplink formats use slots lengths 1, 3 and 5 and these are repeated until all allocated/assigned slots in a Logical Channel are used.

In the default Bulletin Board all uplink data Logical Channels are 30 slots long and may contain 30, 10 or 6 assigned transmissions for burst lengths 1,3 or 5 slots. These slots are assigned using the LC number and a LC Position (LCP). The LC Position number can range from 1 to 90 (7 bit field).

For the default Bulletin Board, a ship can only transmit 3 times during a 1 minute frame. There are also three periods of 12 s when the ship is not transmitting, thereby providing quiet periods when ships with 10s AIS reporting interval can be detected.

Table 2A1-19 shows the Logical Channel parameters for a frequency pair. For VDE-TER the lowest frequency pair starts with LC 0, the 2nd start with 13. Up to 127 LCs can be supported. For VDE-SAT the highest frequency starts with LC 0.

The ship equipment shall prevent any transmission on channels 16 and 70 for all Bulletin Board settings.

Table ~~2~~A1-19~~.~~

Logical Channel definition

Name	Value	Field size (bits)	Comment
Frequency 1: Ship rx Channel Frequency Index (CFI)	156-162.0375 MHz, 12.5 kHz step Channels 0-482 Centre frequency= 156+0.0125*CFI	9	VDES upper leg: 465: 161.8125 MHz (TER default) 469: 161.8625 MHz 473: 161.9125 MHz (SAT default)
Frequency 2: Ship tx CFI	156-162.0375 MHz, 12.5 kHz step Channels 0-482	9	VDES lower leg: 97: 157.2125 MHz (TER default) 101: 157.2625 MHz 105: 157.3125 MHz (SAT default) ASM: 476: 161.950 MHz 480: 162.000 MHz
BB Link Configuration ID Logical channel 0	0-63	6	The symbol rate, bandwidth, burst duration, modulation and coding are defined in Table 4.
BB size in slots	TER: 0, 1, 2, 3 or 5 SAT: 0, 90 or 180	3	Defaults: TER: 5 (011) SAT: 90 (001)
BB data flag	0 or 1	1	Set to 1 if signalling is transmitted on the Bulletin Board Logical Channel. Default 0.
ASM ACK flag	0 or 1	1	Set to 1 if ASM messages either channel is acknowledged. Default 0.
Logical Channel 1			
Tx flag	0 or 1	1	0 for ship receive, 1 for transmit, default 0
Link Configuration ID	0-63	6	
Size in slots	0, 1, 2, 3, 5, 30, 90 or 180	3	Logical channel not used: 0 (000)
Function	TER: 1: RACH 2: ASC 1 3: ASC 2 4: ASC 3 5: ASC 4 6: ASC 5 SAT: 1: RACH 2: ASC 3: ASC/Data down 4: Data Down 5: Data Up	3	Default: TER: Fig xx SAT: Fig yy
…………………			Frequency + BB= 29 bits Each Logical Channel=13 bits
Logical Channel N TER: N=6 SAT: N=12			
Tx flag	0 or 1	1	0 for ship receive, 1 for transmit, default 0
Link Configuration ID	0-63	6	
Size in slots	0, 1, 2, 3, 5, 30, 90, 180	3	Default: 90 (111) Not used: 0 (000)

Function	TER: 0: Bulletin Board 1: RACH 2: ASC general 3: ASC 1 4: ASC 2 5: ASC 3 6: ASC 4 7: ASC 5 SAT: 0: Bulletin Board 1: RACH 2: ASC 3: ASC/Data Down 4: Data Down 5: Data Up	3	Default: TER: Fig xx SAT: Fig yy
	Total/Channel	TER: 14 Bytes SAT: 24 Bytes	TER: 29+ 6*13+ 5 spare=112 bits=14 B SAT: 29+12*13+7 spare=192 bits=24 B
	Total 3 channels	TER: 42 B SAT: 72 B	

5.3.105.3.-3 Configuration Message

The Configuration Message, Table A1-20, has a variable length data format and is used to handle additional information that is not defined or does not fit within the Bulletin Board.

Commenté [JC48]: Add in text to refer to the table.

Table A1-20

3. Configuration Message construction (variable fields)

Name	Description	Total size (bytes)	Comment
Channel Formats	Additional frequencies/slot usage	42/72	TER/SAT new channel
Free text message	Containing up to 254 ASCII characters	256	Network operator message to all ships, information only. Includes 8 bit packet type and 8 bit message length
Padding	A zero filling sequence with no content.	3	Includes 8 bit packet type and 16 bit length

5.3.15.3.4 Digital Signature of Bulletin Board {DRAFT, requires further work}

It is assumed that a Public Key Infrastructure (PKI) is established with primarily IMO as Certificate Authority (CA), and that ITU-T X.509 (10/2016) is used for public key certificates and the PKI implementation. The PKI will serve several systems and among these VDES. For VDES the primary purpose is to attach a digital signature to the Bulletin Board (BB) issued by a VDES control station to authenticate the control station transmitting the BB.

Ships will need to retrofit a dedicated PKI unit to their bridge system, or build the functionality into the VDES equipment. This unit provides cryptographic services to both general and bridge network applications. The unit will utilize a smartcard for tamper-proof storage of the security credentials.

In case the verification of the signature fails on the VDES mobile station this shall be flagged to the user {Rephrase, we have no display}. The system shall continue its operation as if the signature was verified.

Cryptographic algorithm for the end-entities digital signatures is the Elliptic Curve Digital Signature Algorithm (ECDSA). The Elliptic Curve Cryptography (ECC) public key shall therefore be 256 bit. With this key size, the recommendations from RFC 5480 states that the minimum bits of security should be 128, the message digest algorithm SHA-256, and the curve secp256r1. The lifetime of the selected key material is 3 years. [*Paragraph TBD based on available space in BB. Refer to ch 3.5.3 in d2.2 from CySiMS*].

Communication with separate PKI unit shall be based on network protocol. [*Standard for message exchange TBD*] [Ref to IEC 61162-450 and -460?]

5.4 Network layer

This layer is responsible for the management of priority assignments of messages, distribution of transmission packets between channels and data link congestion resolution.

5.4.1 Data transfer protocols

The following downlink protocols shall be supported:

- Shore originated multicast
- Shore originated unicast
- Ship originated short message
- Ship to ship unicast inside/outside controlled areas (note for Hans , new drawing)
- Ship to ship short message
- Shore originated short message
- Control Station-to-ship; Bulletin board transmission
- Control Station-to-ship; Multicast
- Control Station-to-ship; Unicast
- Ship-to-ship; Multicast
- Ship-to-ship; Unicast
- Ship-to-Control Station single packet data transfer; Unicast
- Ship-to-Control Station multi-packet data transfer; Unicast

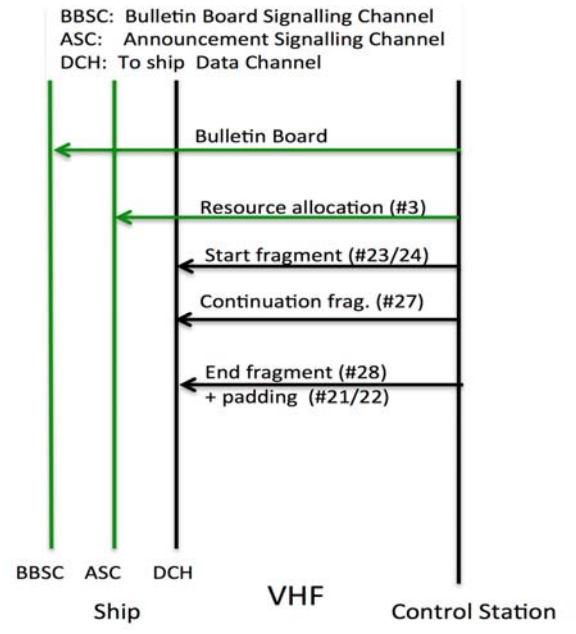
5.4.1.1 Shore originated Multicast without ACK

The timing diagram for shore originated multicast without ACK is shown in figure xxx7A1-19. The transfer starts with a resource allocation. The diagram shows a large multi-fragmented datagram. Both predefined groups and geographical areas are supported.

The datagram payload has source, destination and format encapsulated for routing and presentation purposes.

FIGURE A1-19

multicast timing diagram



~~Fig xxx7. Multicast timing diagram~~

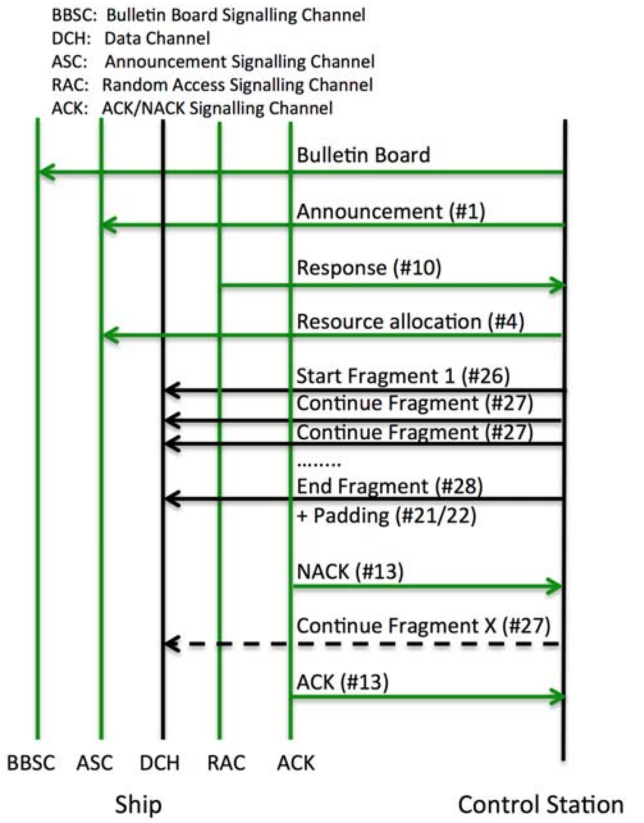
5.4.1.2 Shore originated Unicast

The timing diagram for shore originated unicast is shown in figure ~~xxx~~8A1-20. The transfer starts with a ship/ ship paging to verify that it is within coverage. The ships response packet contains terminal capabilities and received signal quality. At the Control Station this is used to allocate an exclusive Logical Channel for the transfer. The diagram shows a large multi-fragmented datagram. Normally up to 16 fragments are sent before the ship sends a selective NACK indicating which fragments have to be resent. The Logical Channel is kept allocated until all fragments have been received by the ship and a ACK has been received or a retry limit has been exceeded.

The datagram payload has source, destination and format encapsulated for routing and presentation purposes.

FIGURE A1-20

To ship Unicast protocol timing diagram



~~Fig. xxx8. To ship Unicast protocol timing diagram~~

5.4.1.3 Ship orginated short message

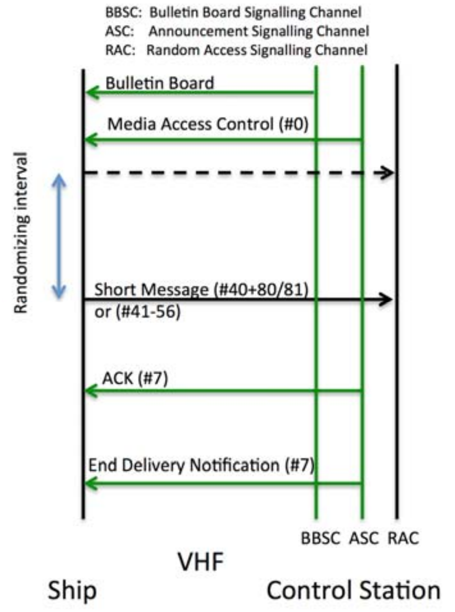
The timing diagram for ship originated short message is shown in figure A1-21. This protocol is used for short messages that fit within a single transmission burst. A random slot in the randomizing interval given in the MAC signalling is used for the transmission. Zero padding is added as required. 16 byte IPv6 addressing is used.

When maximum robustness is needed a special fixed 11 byte packet is used. 16 different packet types define the content. All types can select from 255 pre-assigned terrestrial addresses. A 16 bit CRC is used for these packets.

The Control Station sends and ACK when the message is received correctly, otherwise the ship may automatically retry until the retry limit is reached.

FIGUREA1-21

Short message protocol timing diagram



~~Figure xxx. Short message protocol timing diagram~~

5.4.1.4 Ship orginated data transfer

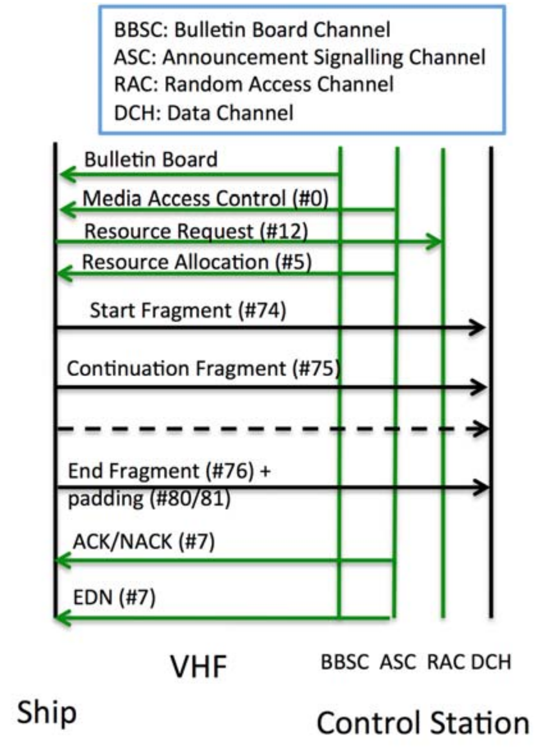
The timing diagram for ship originated data transfer is shown in figure ~~xxx10~~A1-22. The transfer starts with the ship requesting Control Station resources. The Control Station allocate an exclusive Logical Channel for the transfer. The diagram shows a large multi-fragmented datagram. Normally up to 16 fragments are sent before the Control Station sends a selective NACK indicating which fragments have to be resent. The Logical Channel is kept allocated until all fragments have been

Commenté [JC49]: Consider adding in text at the beginning, similar to others: 'The timing diagram is shown in figure xxx' received by the Control Station and the final ACK has been received or the retry limit has been exceeded.

The End Delivery Notification is optional and defined in the datagram payload, it is mainly used in store-and-forward systems.

FIGURE A1-22

Ship originated datagram



~~Fig. xxx10. Ship originated datagram~~

5.4.1.5 Ship to ship short message

Resource and mobility management

Ships outside the Control Station range may communicate directly. In this case AIS receptions may be used to determine if a ship is within range, combined AIS/VDES transceivers will set a bit in their periodic AIS report that indicates VDES support.

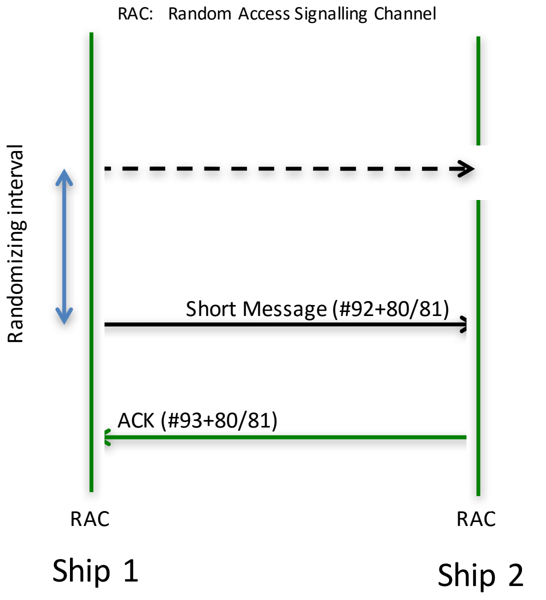
To minimize transmissions to ships outside communications range, sending short messages or paging other ships shall not use more than 1% of the signaling channel (LC 0) slots when the signaling channel is loaded less than 1% averaged over 1 minute. During heavier loading, the activity rate shall be reduced to 0,01%.

The protocol timing for ship to ship short message transfer is shown in FIGUREThe timing diagram for ship to ship short message is shown in figure A1-23.

Commenté [JC50]: placeholder for diagram

New text and timing diagram from Hans coming

FIGURE A1-23 SHIP TO SHIP SHORT MESSAGE TRANSFER DIAGRAM



[title to come]

5.4.1.6 Ship to ship communications

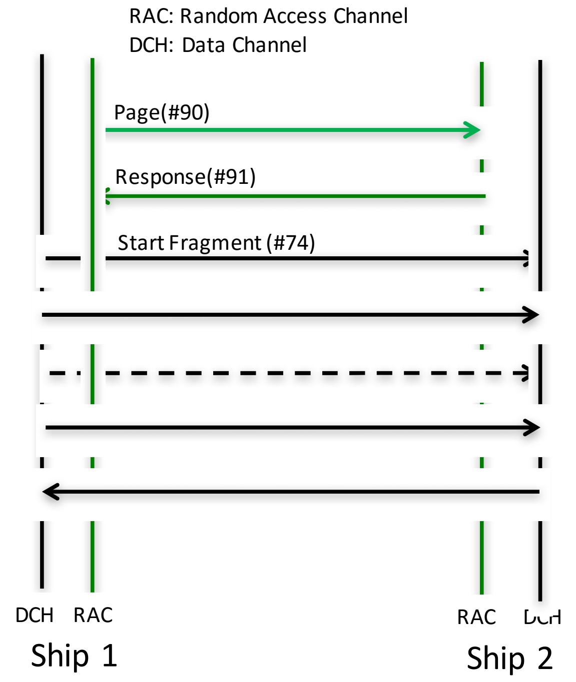
Ship to ship communications uses a modified RATDMA protocol where up to 6 Logical Channels are defined. Logical Channel 0 is used for signaling. The called ship selects the most quite channel.

The timing diagram for ship to ship communications is shown in figure A1-24. Ship to ship communications uses a modified RATDMA protocol where up to 6 Logical Channels are defined. Channel 0 is used only for signalling, whilst the originating ship selects the most quiet Logical Channels for communications.

Commenté [JC51]: Consider adding in text at the beginning, similar to others: 'The timing diagram is shown in figure xxx'

FIGURE A1-24

Ship to ship protocol timing diagram ~~Figure xxx. shows the protocol timing diagrams.~~


RAC: Random Access Channel
DCH: Data Channel
Page(#90)
Response(#91)
Start Fragment (#74)
DCH
RAC
Ship 1
RAC
Ship 2

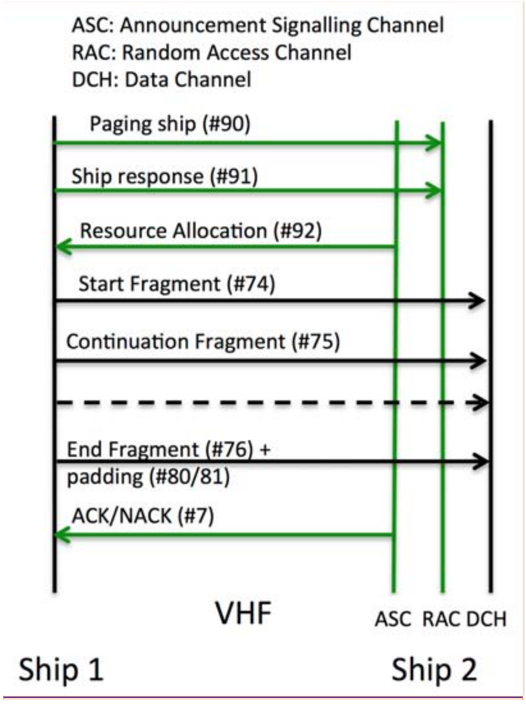


Figure xxx. Ship to ship protocol timing diagram

5.4.1.7 Ship to ship short message

The Control Station service area is defined on its Bulletin Board. Within this service area the Control Station manages the VDES resources to minimize interference.

AIS receptions may be used to determine if a ship is within range, combined AIS/VDES transceivers will set a bit in their periodic AIS reports that indicates VDES support.

The resource is de-allocated by the Control Station if the called ship is unreachable.

Field 4 in packet type #6 is set to 11 if the destination ship is not reachable. The timing diagram for ship to ship short message is shown in figure

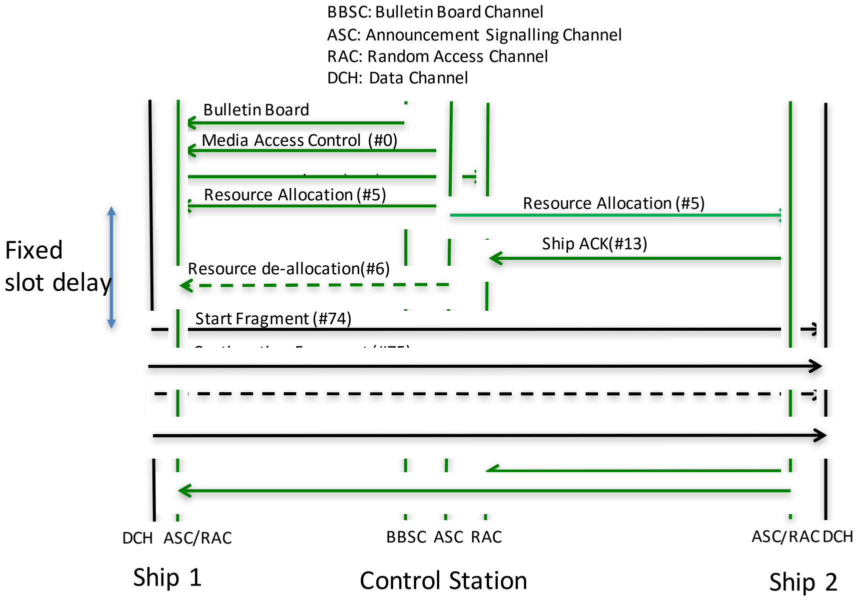
See the protocal timing diagram in FIGURE A1-23.

Commenté [A52]: Second arrow (or first) has the wrong direction

Commenté [JC53]: placeholder for diagram

FIGURE A1-23

SHIP TO SHIP SHORT MESSAGE VIA CONTROL STATION DIAGRAM

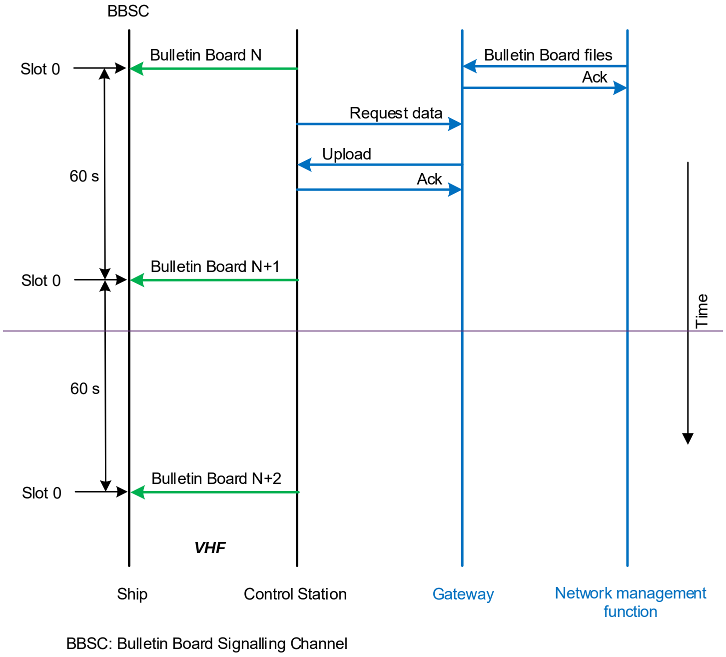


~~New text and timing diagram from Hans coming~~

~~[confirm with 5.4.1.5 – same title]~~

~~FIGURE A1-15 – SHIP TO SHIP UNICAST… SHIP TO SHIP…~~

~~FIGURE A1-10 – BULLETIN BOARD WITH NETWORK VERSION CHANGE~~



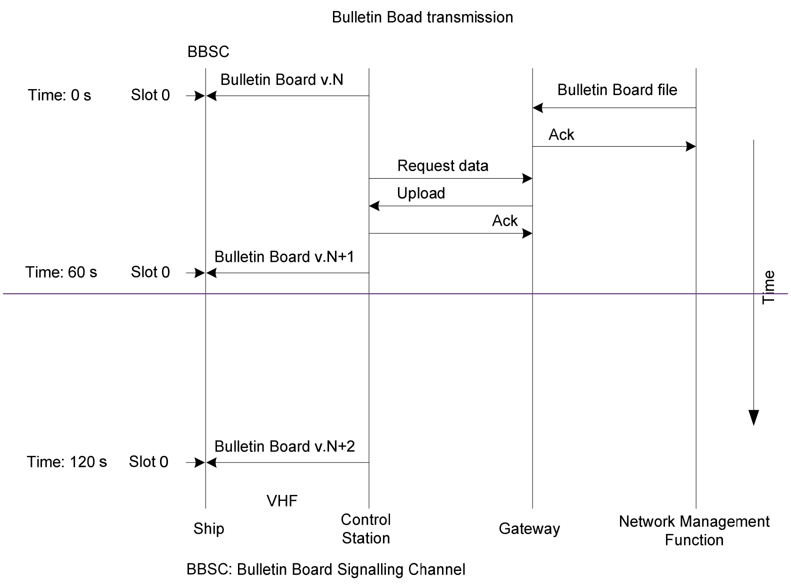
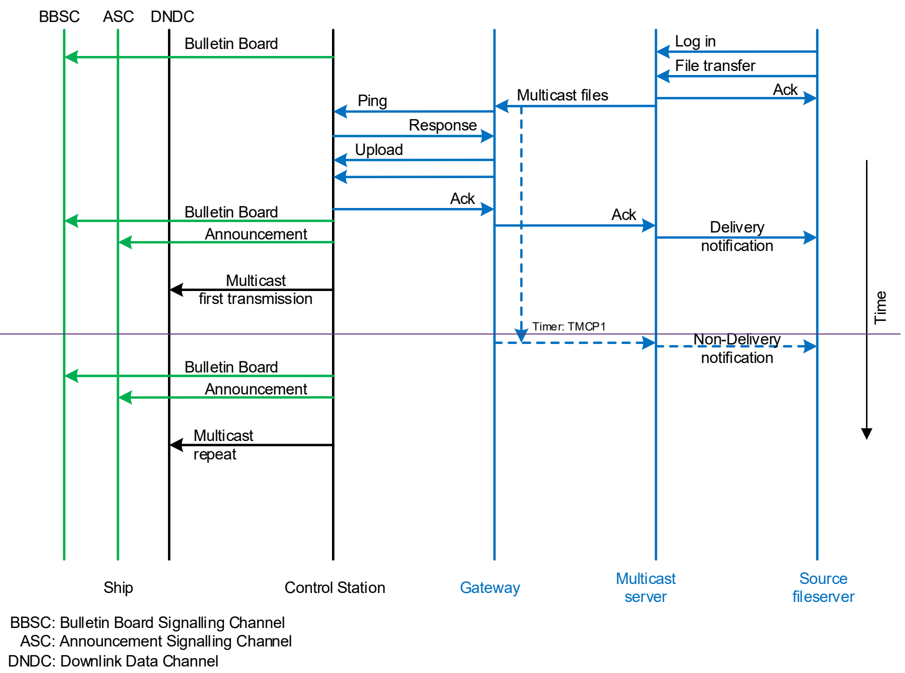
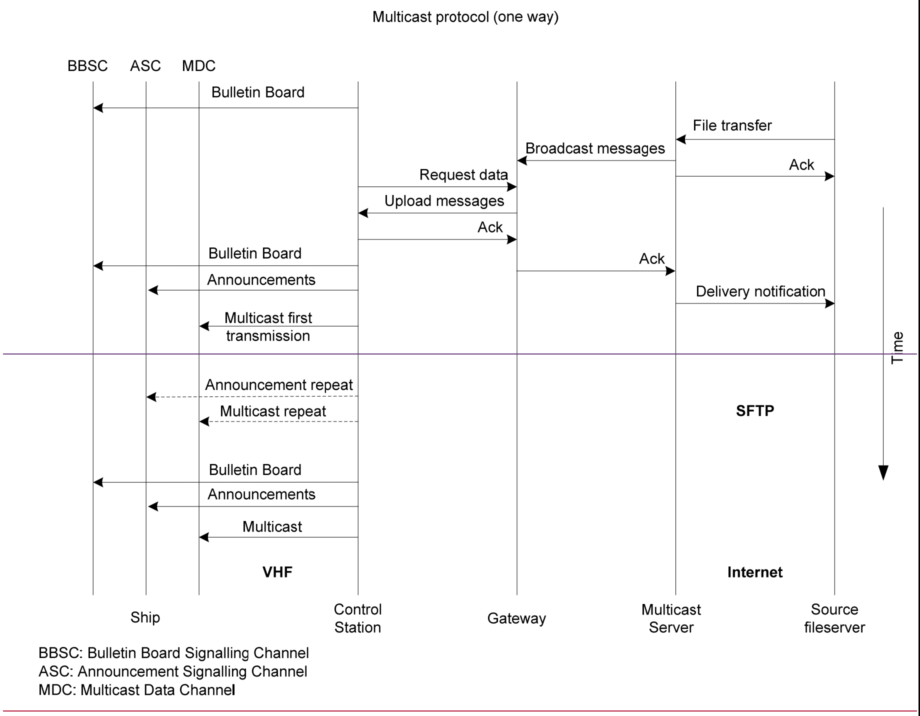
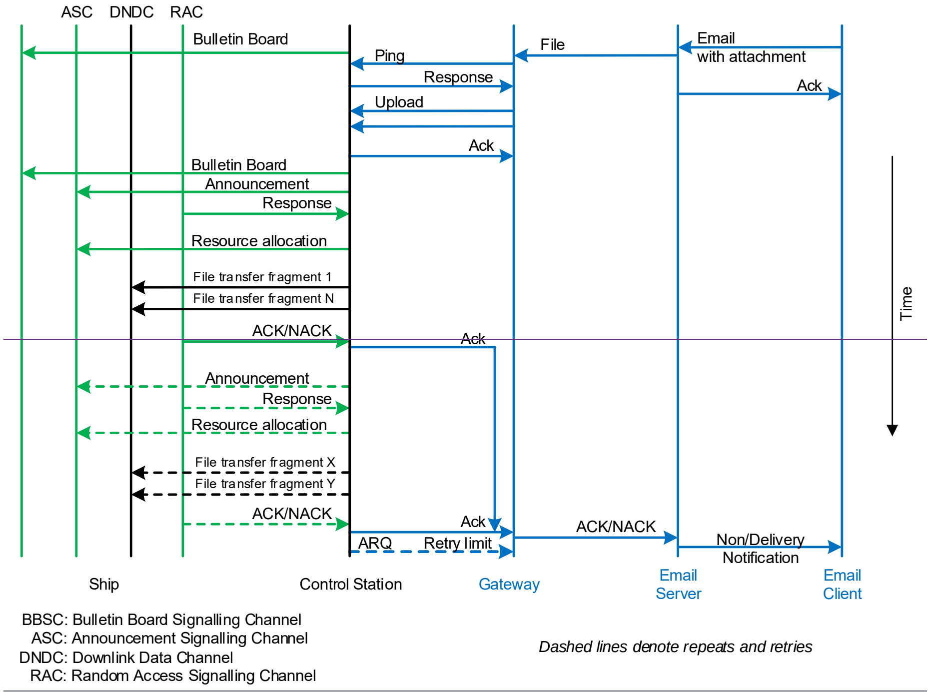


FIGURE A1-11 - MULTICAST PROTOCOL (ONE-WAY)

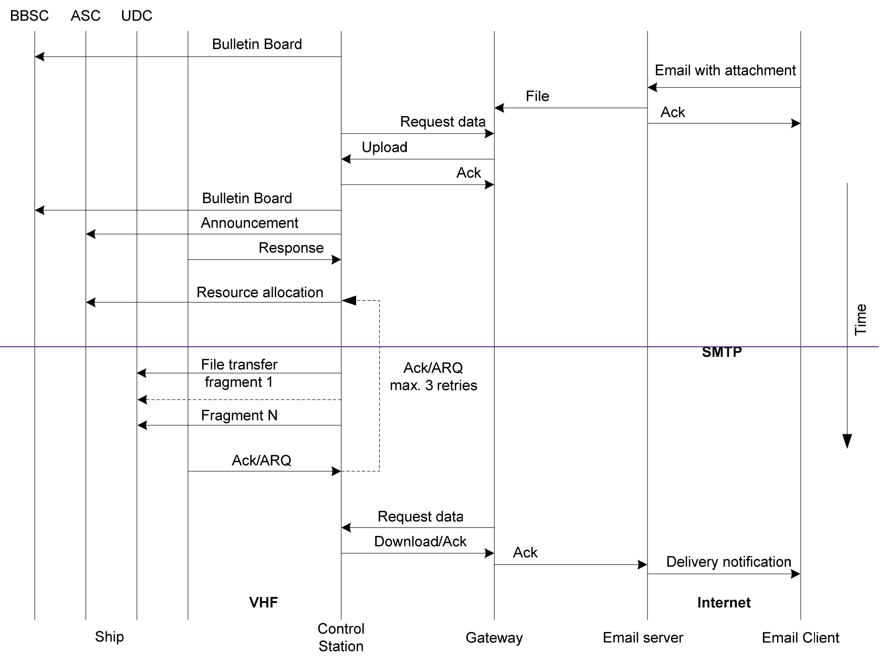



Multicast protocol (one way)
BBSC
ASC
MDC
Bulletin Board
File transfer
Broadcast messages
Ack
Request data
Upload messages
Ack
Bulletin Board
Ack
Announcements
Delivery notification
Multicast first transmission
Time
Announcement repeat
Multicast repeat
SFTP
Bulletin Board
Announcements
Multicast
VHF
Internet
Ship
Control Station
Gateway
Multicast Server
Source fileserver
BBSC: Bulletin Board Signalling Channel
ASC: Announcement Signalling Channel
MDC: Multicast Data Channel

~~FIGURE A1-12 – SHORE ORIGINATED UNICAST (FILE TRANSFER) PROTOCOL~~

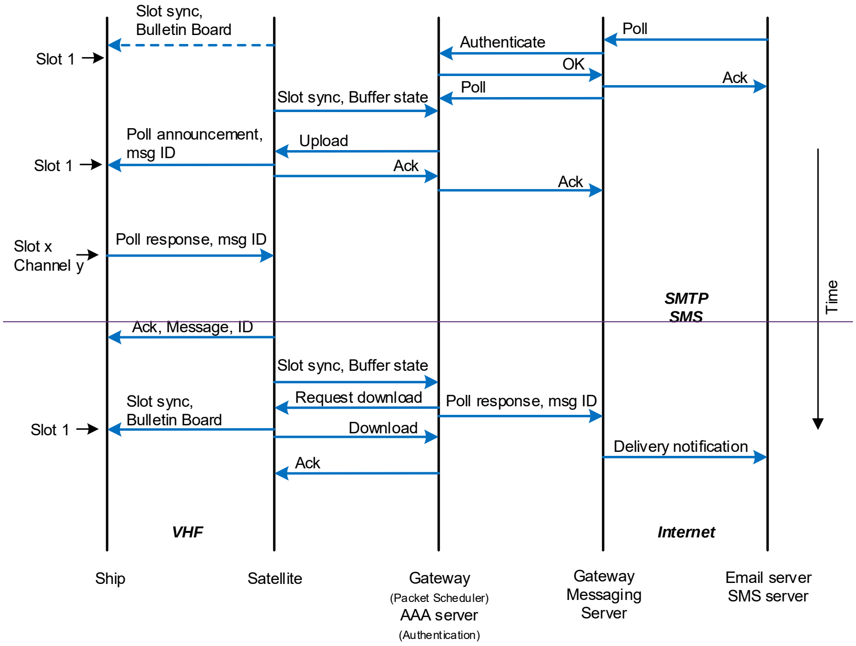


Shore originated unicast protocol

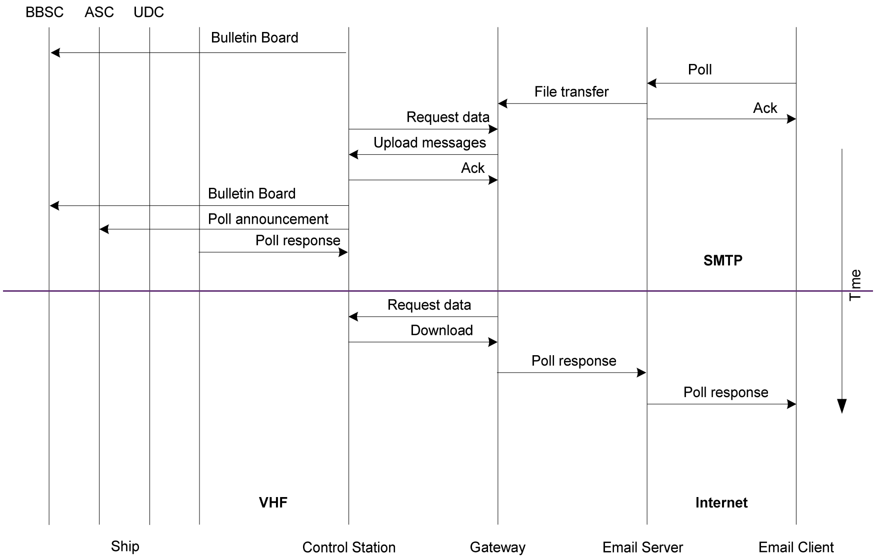


BBSC: Bulletin Board SignallingCchannel
ASC: Announcement Signalling Channel
UDC: Unicast Data Channel

~~FIGURE A1-13 – SHORE ORIGINATED POLL PROTOCOL~~

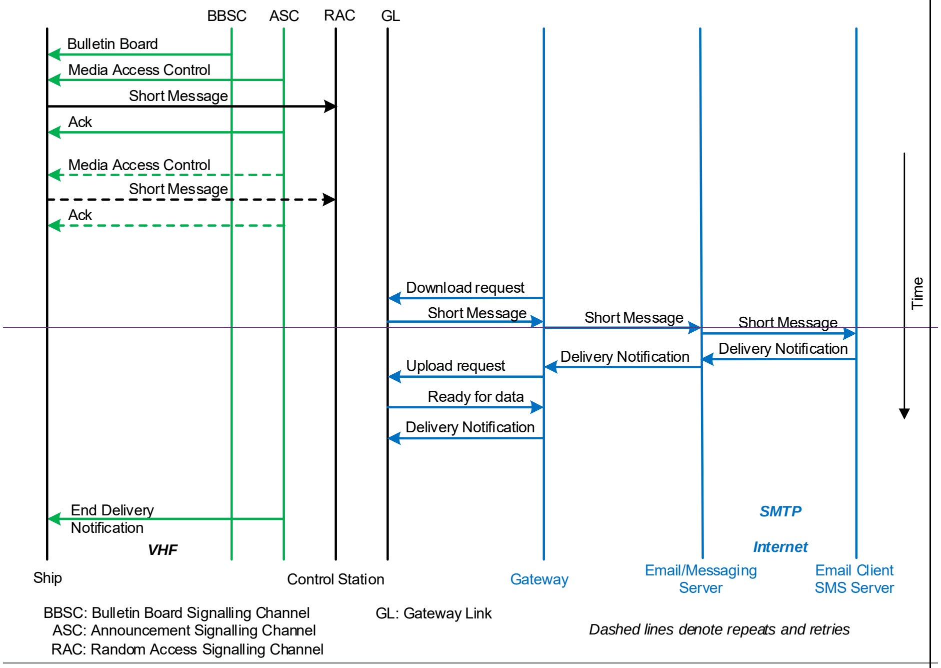


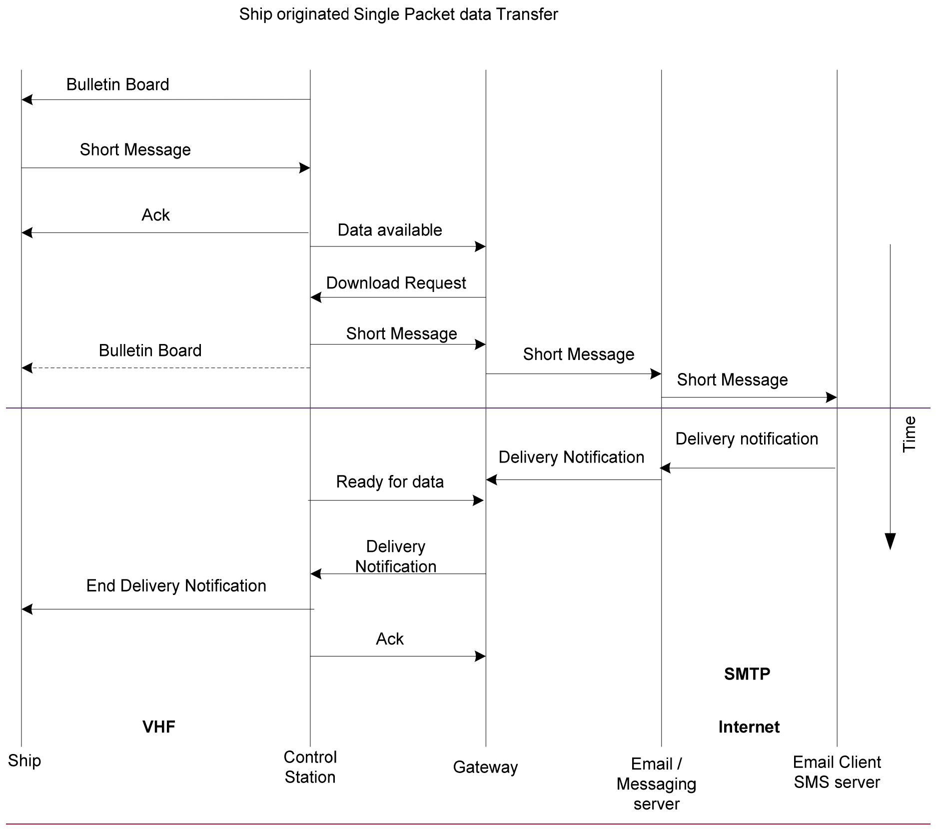
Shore Originated Poll Protocol (Satellite)



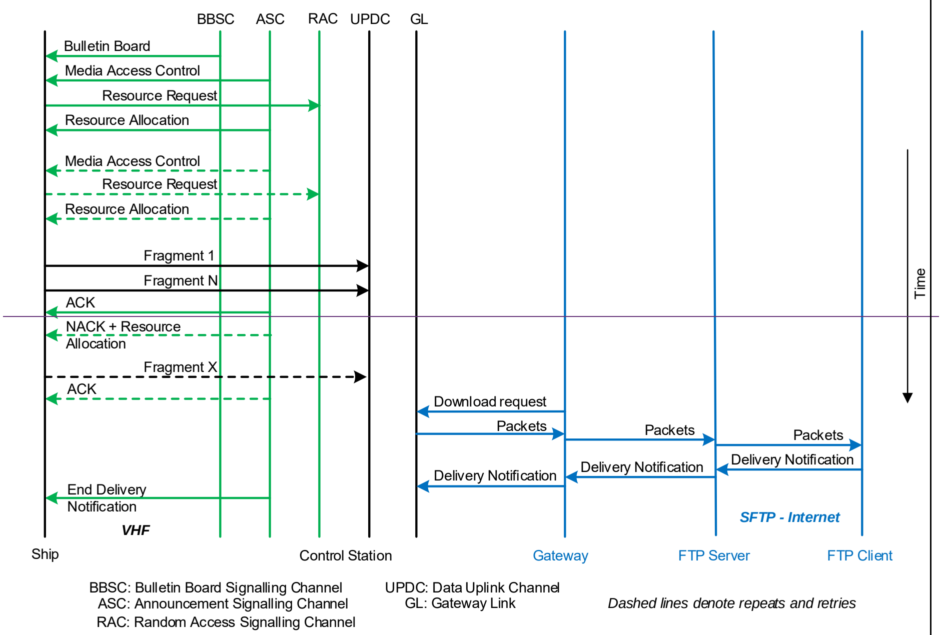
BBSC: Bulletin Board Signalling Channel
ASC: Announcement Signalling Channel
UDC: Unicast Data Channel

~~FIGURE A1-14 – SHIP ORIGINATED SINGLE PACKET DATA TRANSFER~~

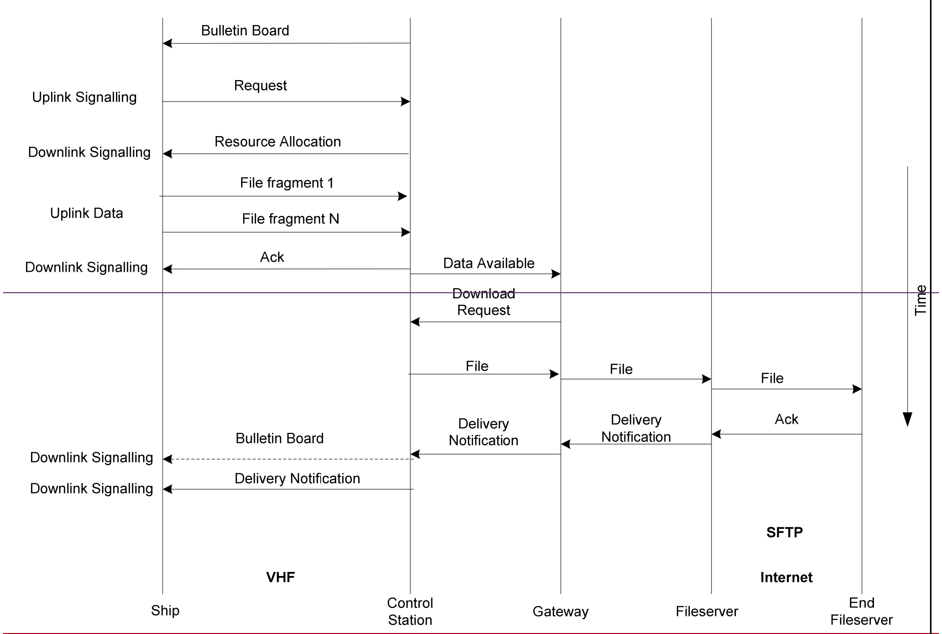



Ship originated Single Packet data Transfer
Bulletin Board
Short Message
Ack
Data available
Download Request
Short Message
Bulletin Board
Short Message
Short Message
Time
Delivery notification
Delivery Notification
Ready for data
Delivery Notification
End Delivery Notification
Ack
SMTP
VHF
Internet
Ship
Control Station
Gateway
Email / Messaging server
Email Client SMS server

~~FIGURE A1-15 – SHIP ORIGINATED MULTI-PACKET DATA TRANSFER~~



Ship originated Multi-Packet data Transfer



5.53.2.1 Transport layer

This layer ensures reliable transmission of the data segments between ships, ship and shore, and ship and satellite, including segmentation, acknowledgement and multiplexing.

5.5.1 Presentation interface protocol

Data, which is to be transmitted by the station, may be input via the presentation interface; data, which is received by the station, should be output through the presentation interface. The formats and protocol used for this data stream are defined by IEC 61162 series.

3.2.1.15.5.12 End to end protocols

Existing Internet protocols such as UDP, SNMP, secure file transfer protocol (SFTP), simple mail transfer protocol (SMTP) as shown in Figs. A4-10 to A4-15 are used.

Terrestrial IP protocols are assumed to be terminated at the satelliteControl Station gateway.

3.2.1.25.5.2 3 Ship, application gateway and device physical addressing

Most commercial ships use a 7-digit IMO number of which the last is a checksum, thus the IMO system can address 1 million ships. The 4 byte VDES physical addressing field has 4.3×10^9 unique IDs. The Control Station or the access network will therefore include a Network Address Translator that converts either a 16 byte IPv6 address or a 7 digit IMO number to this 4 byte ship ID.

The number of networked applicatioins / devices on ships is growing fast and there is a need to directly address local gateways and devicesthe datagrams will, where needed, include sub addresses.

In addition to the 4 byte address field, a 2 byte sub addressing field has been added.

The ship, local gateway and device addressing are shown in Table A1-412. Unlike MMSI, there will be no dedicated field or segmentation in this addressing scheme.

TABLE A1-124

Ship, Gateway and Device addressing

Addressing field	Usage	Range
32 bit physical address (all messages)	Ship Terminal ID	4.3 Billion
16 bit sub addressing	To address local gateways and transducers	Flexible, e.g. 16 gateways each with 4 096 transducers

5.5.4 Terrestrial network addressing

IPv6 with 16 byte addressing is used.

To support multiple connections/applications from a ship, up to 255 sessions with unique IDs can be supported, these can be routed to different IPv6 addresses.

5.5.5 Mobility management

Last transaction coarse position or AIS location data stored in the Control Station database is used to route paging of ships.

Commenté [JC54]: Confirm the rest of the section is to be deleted

3.2.1.35.5.36 Shore addressing of ships, gateways and devices

VDES will be accessed from shore using Internet, and it is desirable to use standard protocols such as email.

A database at the gateway will allow shore users to define their own meaningful ship, gateway and device names.

3.2.2 Network layer

This layer is responsible for the management of priority assignments of messages, distribution of transmission packets between channels and data link congestion resolution.

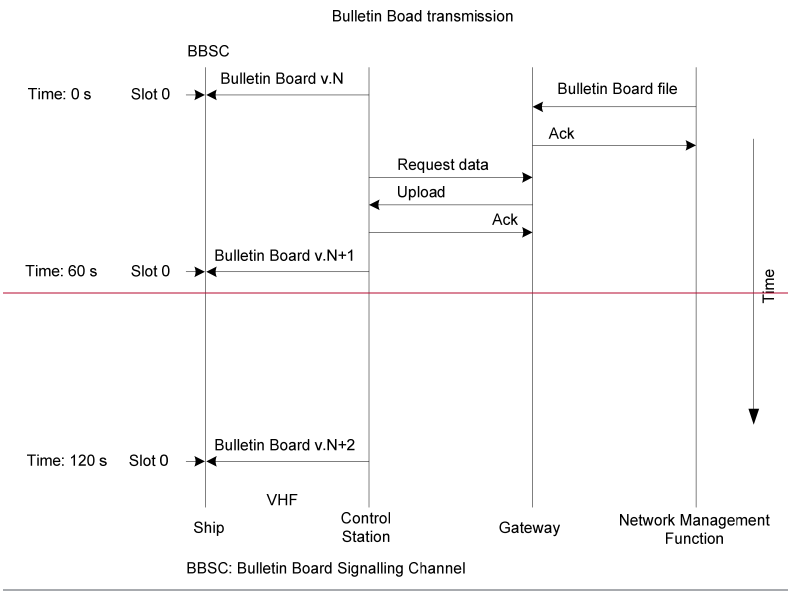
3.2.2.1 Data transfer protocols

The following downlink protocols shall be supported:

– Control Station-to-ship; Bulletin board transmission (network configuration)
– Control Station-to-ship; Multicast (one-way) (icemaps, weather info, notices to mariners)
– Control Station-to-ship; Unicast (file transfer, up to 100 kBytes)
– Ship-to-ship; Multicast (one-way) (icemaps, weather info, notices to mariners)
– Ship-to-ship; Unicast (file transfer, up to 100 kBytes)
– Ship-to-Control Station single packet data transfer; Unicast (short messages)
– Ship-to-Control Station multi-packet data transfer; Unicast (file transfer, up to 100 kBytes)

FIGURE A1-3

Bulletin board with network version change



Commenté [SPI55]: I propose to replace email wit

Commenté [JC56]: Confirm what happens here – deteled?

Commenté [SPI57]: 100kB per which unit?

Commenté [SPI58]: 100kB per which unit?

Commenté [SPI59]: per which unit?

~~FIGURE A1-4~~

~~**Multicast protocol (one-way)**~~

Multicast protocol (one way)

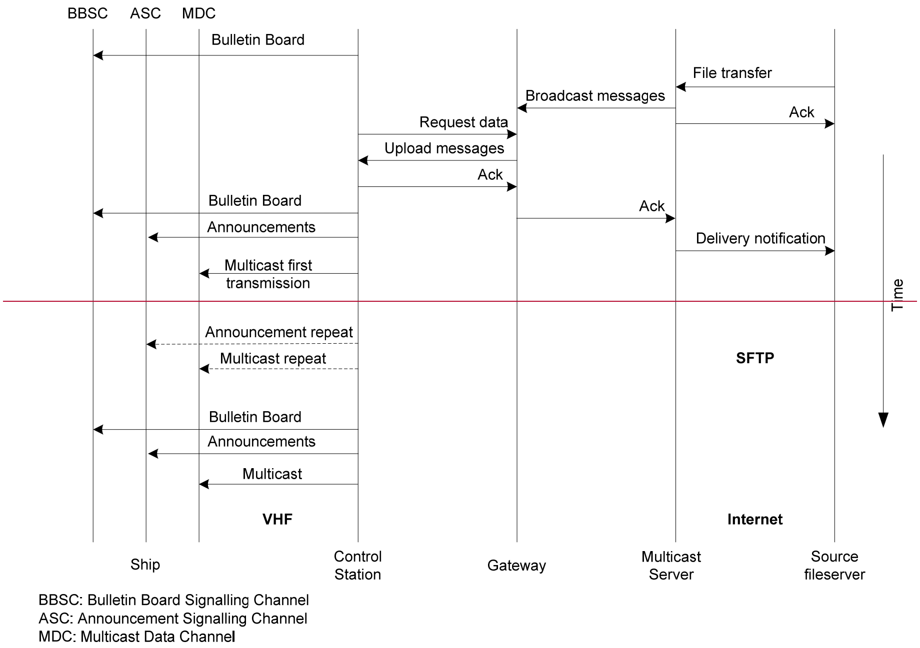
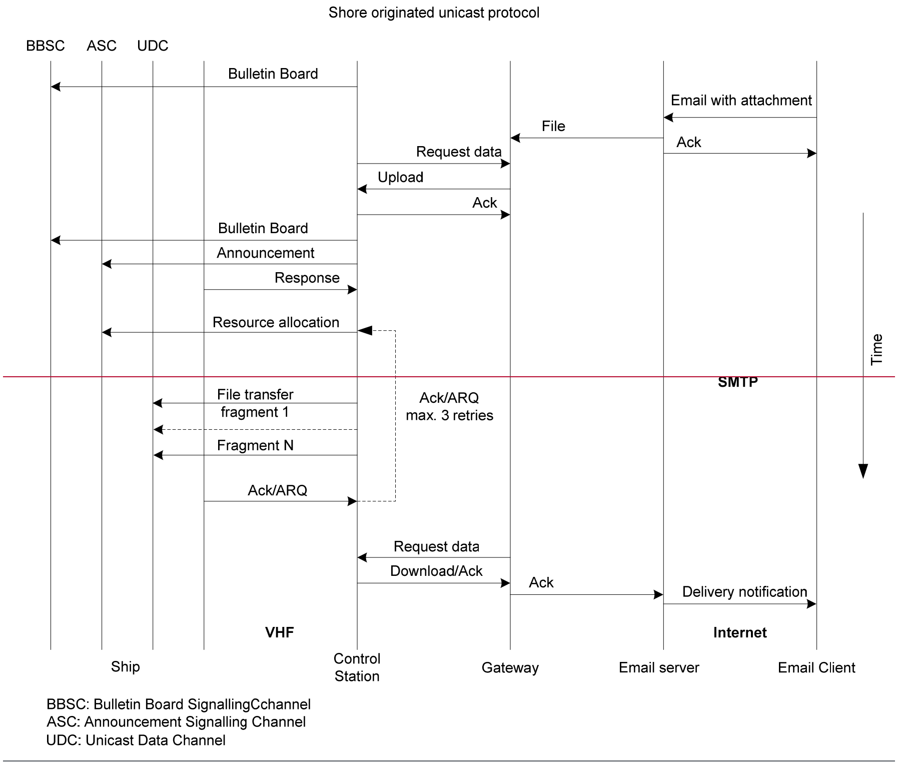


FIGURE A1-5

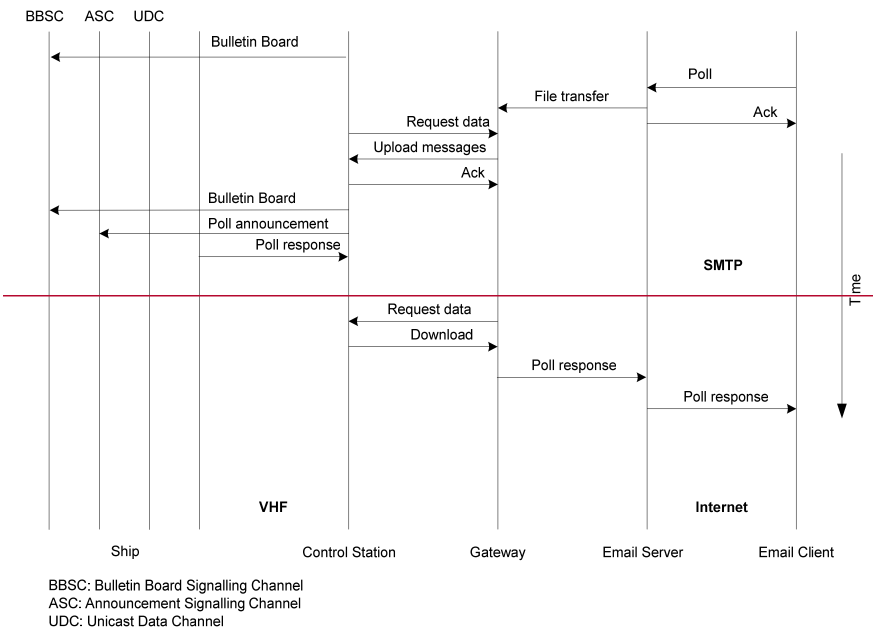
Shore originated unicast (file transfer) protocol



~~FIGURE A1-6~~

~~**Shore originated poll protocol**~~

Shore Originated Poll Protocol (Satellite)



~~FIGURE A1-7~~

~~**Ship originated single packet data transfer**~~

Ship originated Single Packet data Transfer

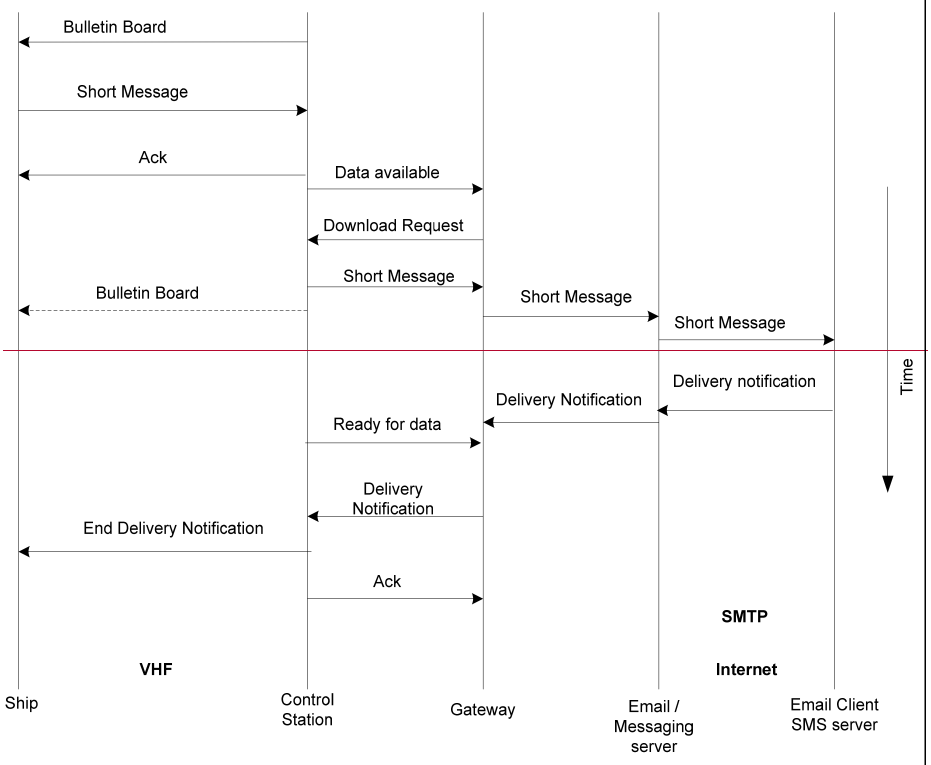
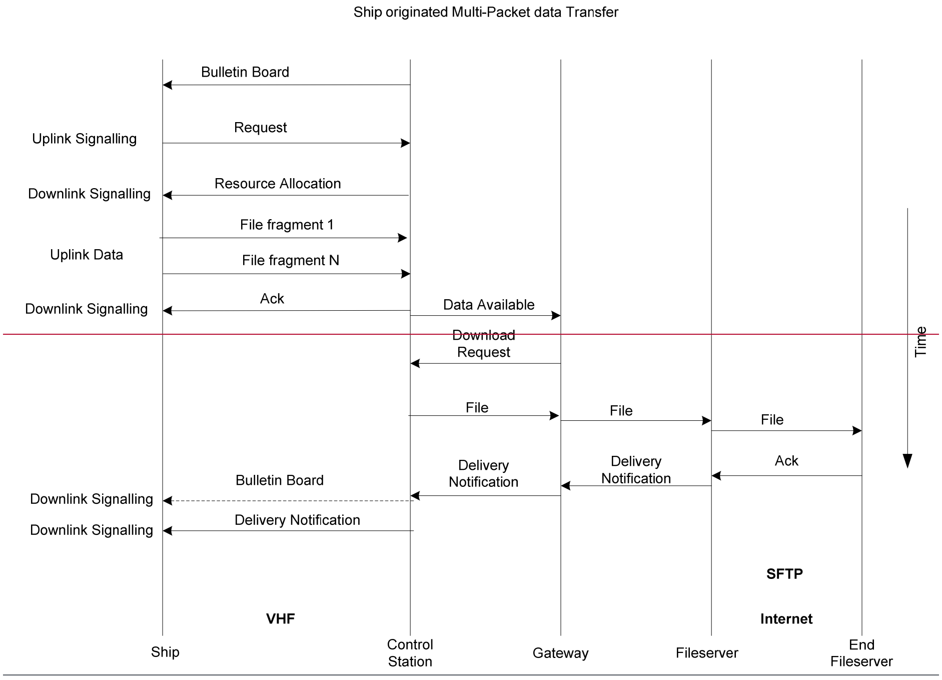


FIGURE A1-8

Ship originated multi-packet data transfer



3.2.3 Link layer

This layer ensures reliable transmission of data frames between ships, ship and shore, and ship and satellite. The link layer is divided into three sub-layers with the following tasks:

3.2.3.1 Link management entity

Assemble unique word, format header, Physical Layer Frame (PL-Frame) headers, pilot tones (satellite) and VDES message bits into packets.

3.2.3.2 Data link services

Calculates and adds CRC check sum and completes the PL-Frame/packet.

3.2.3.3 Media Access Control

Provides methods for granting data transfer access.

3.2.3.4 Data encapsulation

The data segments of each PL-Frame contain multiple variable length encapsulated datagrams. Each datagram contains the following encapsulation fields:

– Datagram type (1 byte)

– Datagram size (3 bytes)

~~Ship ID (4 bytes)~~
~~Transaction ID (4 bytes, optional)~~
~~Datagram sequence number (2 bytes, for multisegment datagrams)~~
~~Source ID (8 bytes, optional)~~
~~Datagram payload (variable)~~
~~Data padding (variable, less than 8 bits)~~
~~CRC (4 bytes).~~

~~3.2.3.5 Cyclic redundancy check~~

~~Refer to § 3.6.~~

~~3.2.3.6 Automatic repeat request (ARQ)~~

~~Datagrams may or may not use ARQ, this is defined for each datagram type. An ARQ will request selective retransmission of a specific lost datagram segment.~~

~~3.2.3.5 Acknowledgement (ACK)~~

~~All datagrams without CRC errors are acknowledged over the satellite link.~~

~~3.2.3.6 End delivery notification (EDN)~~

~~All datagrams successfully delivered to the destination will be notified to the source.~~

~~3.2.3.7 End delivery failure (EDF)~~

~~All datagrams not successfully delivered within the timeout or retry limit will be notified to the source.~~

~~3.2.3.8 Physical and logical channels~~

~~[Content to be provided by Krzyzstof and Hans]~~

~~3.2.3.8.1 Physical channels~~

~~[Content to be provided by Krzyzstof and Hans]~~

~~3.2.3.8.2 Logical channels~~

~~[Content to be provided by Krzyzstof and Hans]~~

~~3.2.3.8.2.1 Signalling logical channels~~

~~[Content to be provided by Krzyzstof and Hans]~~

~~3.2.3.8.2.2 Bulletin board signalling channel~~

~~[Content to be provided by Krzyzstof and Hans]~~

~~3.2.3.8.2.3 Announcement signalling channel (ASC)~~

~~[Content to be provided by Krzyzstof and Hans]~~

~~3.2.3.4.2.4 Multicast data channel (MDC)~~

~~[Content to be provided by Krzyzstof and Hans]~~

3.2.3.4.2.5 Unicast data channel (UDC)

[Content to be provided by Krzyzstof and Hans]

3.2.4 Physical layer

This layer provides transmission and reception of raw bit streams over a physical medium including signal modulation, filtering/shaping upon transmission, and amplification, filtering, time and frequency synchronization, demodulation, and decoding upon reception.

3.2.4.1 Transmission accuracy figures

3.2.4.1.1 Symbol timing accuracy (at the output)

The timing accuracy of the transmit signal should be better than 5 ppm.

3.2.4.1.2 Transmitter timing jitter

The timing jitter should be better than 5% of the symbol interval (peak value).

3.2.4.1.3 Slot transmission accuracy at the output

The slot transmission accuracy should be better than 50 µs peak relative to UTC time reference for control stations (e.g. shore station or satellite).

The slot transmission accuracy should be better than 100 µs peak relative to UTC time reference for ship stations.

3.3 Frame Structure

The system uses the Recommendation ITU-R M.1371 concept of a frame. A frame equals one (1) minute and is divided into 2 250 slots. Access to the data link is, by default, given at the start of a slot. The frame start and stop coincide with the UTC minute. The VDES frame structure is identical and synchronized in time to UTC (as in AIS). The general slot format is shown in Fig. A1-94. Note that "Sync 2" and "Link Configuration Id" are not used by the SAT link. The slot structure for each service is shown in Fig. A1-105. Each element is described in the subsequent sections. Table A1-25 shows the resulting net bitrates (Data bits of the slot structure).

ASM

Bandwitdth

25 kHz

Ramp up	Training sequence	Signal Information	Data	Guard time
8 symbols	27 symbols	7 sym	199 symbols	15 symbol

Commenté [JS60]: This drawing need to be updated with ASM symbol timing as shown belowd. Change the "Buffer" to "Guard Time".
SPI 20160523: done.

Commenté [SP61]: Somebody with Visio, please ;-)

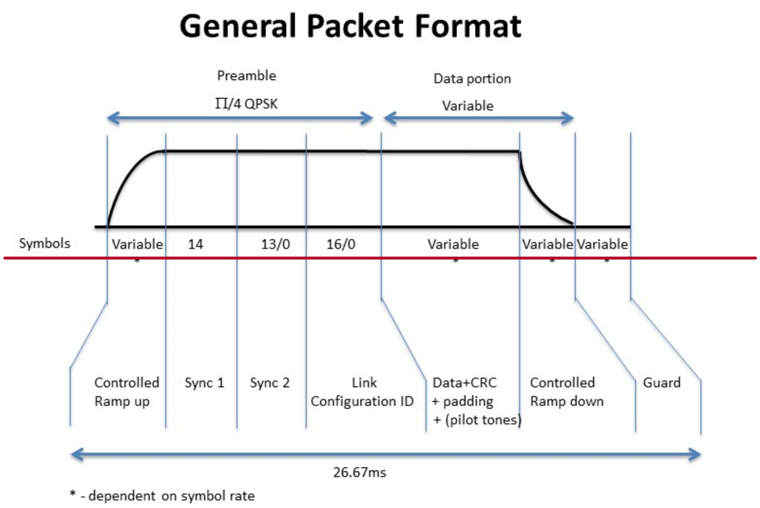
Commenté [JS62]: Add this information to the drawing above

TABLE A1-25

Resulting net bitrates (Data)

NET user data bitrate per channel [kbps][2]			
	Bandwidth		
	25 kHz	50 kHz	100 kHz
VDE MCS-0	13	n/a	n/a
VDE MCS-1	15	32	66
VDE MCS-3	35	74	150
VDE MCS-5	47	100	200

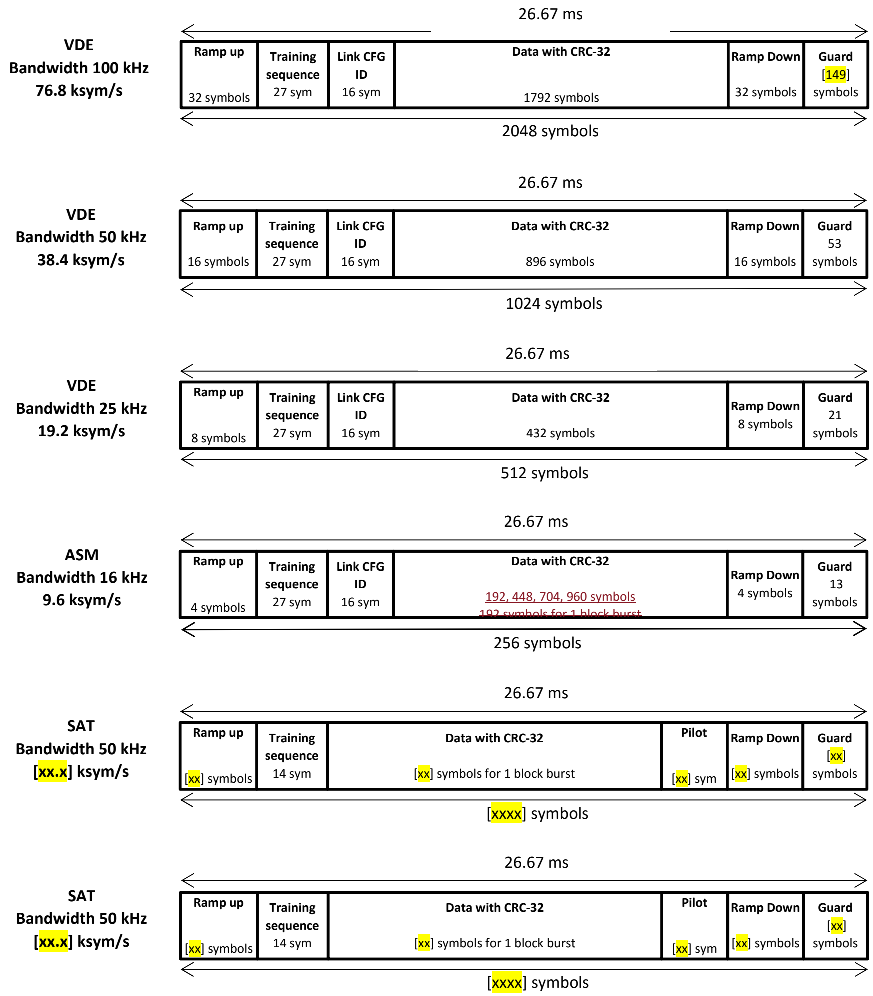
FIGURE A1-94



[2] Amount of aggregate user data which can be carried by the MSC scheme on a single channel assuming single slot packets including coding and other message encapsultion according to the MSC definition.

FIGURE A1-105

Slot structure



3.3.1 Frame hierarchy definition

The frame hierarchy is shown in Fig. A7-21-11. The frame hierarchy definition is independent of the assigned bandwidth to the VDE channel

3.3.1.1 Time slot

The time slot is a time interval of approximately 26.667 ms (60 000 / 2 250 = 80/3 ≈ 26.667).

3.3.1.2 Hexslot

Six timeslots should form a Hexslot (HS). The HS has duration of 160 ms.

The HS should be numbered cyclically from 0 to 4. The HS should be incremented after every 6 time slots.

3.3.1.3 Timeslot numbering

The timeslots within a Hexslot should be numbered from 0 to 5 and a particular timeslot should be referenced by its timeslot number (TN).

3.3.1.4 Uberslot

Five Hexslots should form a Uberslot (US). The US should have duration of 800 ms.

The US should be numbered by a US Number. The US should be cyclically numbered from 0 to 14. The US should be incremented whenever the Hexslot returns to 0.

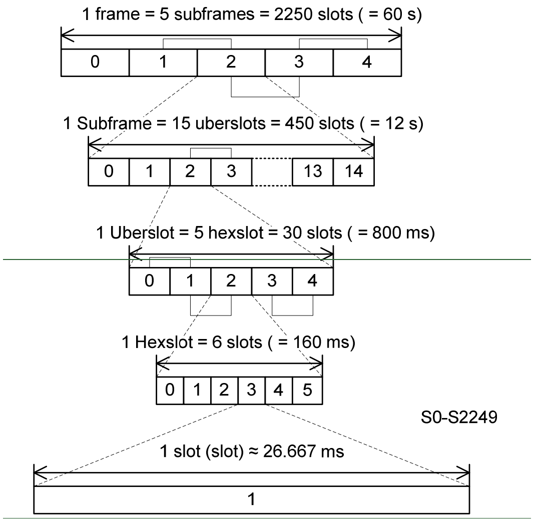
3.3.1.5 Sub frame

Fifteen US should form a sub frame. The sub frame should have a duration of 12 seconds. The sub frame should be numbered by a sub frame nNumber. The PL-fFrame should be cyclically numbered from 0 to 4. The sub frame should be incremented whenever the US returns to 0.

Commenté [SPI63]: PL-frame what's that?

FIGURE A1-116-2

Frame Hierarchy for shared frequency



3.3.12 Ramp up

The ramp-up time from −50 dBc to −1.5 dBc of the power shall controlled rise time and occur in 416 µs. A gradual ramp-up period provides important spectral shaping to reduce energy spread outside the desired signal modulation bandwidth, and reduces interference to other users of the current and adjacent channel.

3.3.23 Training sequence

The training sequence is separated in to two sections with the SAT link only using the first 14 symbols and is defined as 1111110011010100000011001010.

3.3.34 Link Configuration Id

The Link Configuration Id defines the channel configurations. The Link Configuration Id is used to index the table of channel configurations, see Table [x].

The Link Configuration Id follows the training sequence for transmissions, see Figure A1-5.

The Link Configuration Id consists of 6 bits (D0, D1, D2, D3, D4, D5) encoded into a sequence of [16 symbols bits using Hamming (16,6) code].

The link configuration id is not used by the SAT link.

3.3.45 Bit mapping for training sequence and signal information

For training and signal information, following mapping applies:

– 1 maps to π/4 QPSK symbol 3 (1, 1) (see Figure A1-9)

– 0 maps to π/4 QPSK symbol 0 (0, 0).

For π/4 QPSK bit mapping, see § 3.98.

Commenté [SPI64]: Action item 68

Commenté [SPI65]: Action item 68

Commenté [SPI66]: action item 68

Commenté [SPI67]: Action item 68

3.3.56 Data with CRC-32

The data payload with its appended CRC-32 is interleaved (refer to Table A1-2), encoded (refer to § 3.5) and then scrambled (refer § 3.7) and bit mapped.

Unused payload data is zero-filled.

3.93.67 Forward error correction

When forward error correction is used, refer to § 3.5 for details.

3.3.78 Bit scrambling

Scrambling of the user data is required to avoid the power spectral density to be concentrated in the narrow band. Refer to § 3.7 for the detailed definition of the scrambler sequence.

3.3.89 Guard time

The guard time consists of the ramp down time from full power to −50 dBc of less than or equal to 416 µs. The remaining time is for delay and jitter. m

3.4 Presentation interface protocol

For VDES transceivers:

– data may be input via the presentation interface to be transmitted by the VDES station;

– data received by the VDES station should be output through the presentation interface.

3.5 Forward Error Correction

3.5.1 Encoder Structure

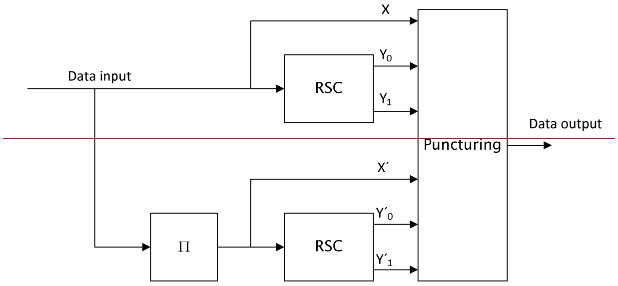
This paragraph defines the general structure of the forward error correction encoder to be used on the satellite and the terrestrial component of the VDES. The overall structure follows the specification in the ETSI EN 302 583 standard {RD-1}.

The general encoder structure is depicted in Fig. A1-1264. The encoder consists of two recursive systematic convolutional (RSC) encoders concatenated in parallel. Each encoder produces 3 output bits per input bit. The first RSC encoder produces the bits X, Y_0 and Y_1, while the second encoder produces the bits X', Y'_0 and Y'_1.

The first encoder gets as input a word **u** of k bits, with k, as specified in § 3.5.3. The second encoder input is denoted by **u**' and it is a permuted version of the vector **u**. The permutation is performed according to the definition provided in § 3.5.3 below.

FIGURE A1-1264

Turbo encoder structure (high-level)



3.5.2 Constituent codes

The constituent codes are specified by the transfer function

$$G(D) = \left[1 \quad \frac{n_0(D)}{d(D)} \quad \frac{n_1(D)}{d(D)}\right]$$

where

$$n_0(D) = 1 + D + D^3$$

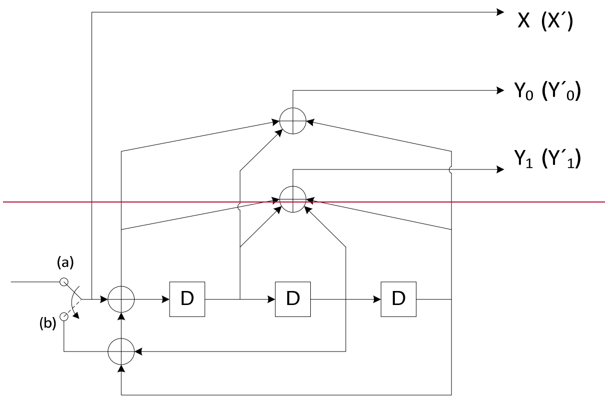
$$n_1(D) = 1 + D + D^2 + D^3$$

$$d(D) = 1 + D^2 + D^3.$$

The constituted encoder definition is provided in Fig. A1-1375. For the first k clocks the switch is in position (a), i.e. information is fed into the encoder. For the subsequent 6 clocks, the switch is moved to position (b) to handle the RSC trellis termination. In the first 3 termination clocks, only the RSC 1 (upper branch) is output, while in the subsequent 3 termination clocks, only the output of RSC 2 (lower branch) is provided. The termination is thus given by the sequence of 6 termination bits (X, Y_0, Y_1, X', Y'_0, Y'_1) with X output first.

FIGURE A1-1375

RSC code encoder



3.5.3 Interleaver definition

The interleaver specification follows {RD-2}.

First factorize $k = k_1 \cdot k_2$, where the parameters k_1 and k_2 depend on the choice of the respective code, where k is the information block length. The values are given in Table A1-362.

TABLE A1-362

Interleaver parameters for different information lengths/code rates

Nominal code rate	Information length	k_1|k_2			
1/4	23552	8|2944			
1/3	128	2|64			
1/2	1920	4|480			
1/2	23056	8|2882			
3/4	136	2|68			
3/4	296	2|148			
3/4	32800	10|3280			

This Table will be extended as different information block lengths are defined.

This FEC will be calculated by first choosing prime numbers p_q, $q \in (1, ..., 8)$

$p_1 = 31$

$p_2 = 37$

$p_3 = 43$

$p_4 = 47$

$p_5 = 53$

$p_6 = 59$

$p_7 = 61$

$p_8 = 67$

The following operations shall be performed for $s \in (1, ..., k)$ to obtain the permutation numbers $\pi(s)$:

$m = (s - 1)\ mod\ 2$

$i = floor\ ((s - 1)\ /(2k_2))$

$j = floor\ ((s - 1)\ /2)) - ik_2$

$t = (19i + 1)\ mod\ (k_1/2)$

$q = t\ mod\ 8 + 1$

$c = (p_q j + 21m)\ mod\ k_2$

$\pi(s) = 2(t + ck_1/2 + 1) - m$

The permutation numbers shall be interpreted such that the s^{th} bit read out after interleaving is the $\pi(s)^{th}$ bit of the input information block.

3.5.4 Rate Adaptation

Rate adaptation is obtained by puncturing the encoder output as in § 5.3.1 of {RD-1}, as recalled in Table A1-43 for the first *k* clocks, and as in {RD-1}.

The puncturing table for the termination part is given in Table A1-473. The last row of the Table is note part of {RD-1}.

Table A1-43 is for the terminations. The last row with ID 8 is introduced in this fdocument to obtain higher rates and is not part of {RD-1}.

TABLE A1-473

Puncturing patterns for data bit periods

<table>
<tr><th>Punc. Pattern ID</th><th>Code Rate</th><th>Punc. Pattern (X; Y0; Y1; X'; Y'0; Y'1 | X; Y0; Y1; X'; Y'0; Y'1 | ...)</th></tr>
<tr><td>0</td><td>1/5</td><td>1;1;1;0;1;1</td></tr>
<tr><td>1</td><td>2/9</td><td>1;0;1;0;1;1 | 1;1;1;0;1;1 | 1;1;1;0;0;1 | 1;1;1;0;1;1</td></tr>
<tr><td>2</td><td>1/4</td><td>1;1;1;0;0;1 | 1;1;0;0;1;1</td></tr>
<tr><td>3</td><td>2/7</td><td>1;0;1;0;0;1 | 1;0;1;0;1;1 | 1;0;1;0;0;1 | 1;1;1;0;0;1</td></tr>
<tr><td>4</td><td>1/3</td><td>1;1;0;0;1;0</td></tr>
<tr><td>5</td><td>2/5</td><td>1;0;0;0;0;0 | 1;0;1;0;0;1 | 0;0;1;0;0;1 | 1;0;1;0;0;1 | 1;0;1;0;0;1 | 0;0;1;0;0;1 | 1;0;1;0;0;1 | 1;0;1;0;0;1 | 0;0;1;0;0;1 | 1;0;1;0;0;1 | 1;0;1;0;0;1 | 0;0;1;0;0;1</td></tr>
<tr><td>6</td><td>1/2</td><td>1;1;0;0;0;0 | 1;0;0;0;1;0</td></tr>
<tr><td>7</td><td>2/3</td><td>1;0;0;0;0;0 | 1;0;0;0;0;0 | 1;0;0;0;0;0 | 1;0;1;0;0;1</td></tr>
<tr><td>8</td><td>3/4</td><td>1;0;1;0;0;0 | 1;0;0;0;0;0 | 1;0;0;0;0;0 | 1;0;0;0;0;0 | 1;0;0;0;0;0 | 1;0;0;0;0;1</td></tr>
</table>

For each rate, the puncturing table shall be read first from left to right and then from top to bottom.

Within a puncturing pattern, a '0' means that the symbol shall be deleted and a '1' means that a symbol shall be passed. A '2' or a '3' means that two or three copies of the symbol shall be passed. This is relevant for the termination periods. In particular

– For the rate 1/5 turbo code (Punct_Pat_ID=0), the tail output symbols for each of the first three tail bit periods shall be XXXY$_0$Y$_1$, and the tail output symbols for each of the last three tail bit periods shall be X'X'X'Y'$_0$Y'$_1$.

– For the rate 2/9 turbo code (Punct_Pat_ID=1), the tail output symbols for the first and the second output period shall be XXXY$_0$Y$_1$, for the third output period XXY$_0$Y$_1$, for the fourth and fifth output period X'X'Y'$_0$Y'$_1$, and for the sixth (last) output period X'X'X'Y'$_0$Y'$_1$.

– For the rate 1/4 turbo code (Punct_Pat_ID=2), the tail output symbols for each of the first three tail bit periods shall be XXY$_0$Y$_1$, and the tail output symbols for each of the last three tail bit periods shall be X'X' Y'$_0$Y'$_1$.

All other code rates shall be processed similar to the given examples above with the exact puncturing patterns to be derived from {RD-1}.

The puncturing table for the termination part is given in Table A1-584. The last row of the table is introduced in this document to obtain higher rates and is not part of {RD-1}.

TABLE A1-584

Puncturing and repetition patterns for tail bit periods (last 6 clocks)

<table>
<tr><th>Punct. Pattern ID</th><th>Code Rate</th><th>Punct. / Rep. Pattern (X; Y_0; Y_1; X'; Y'_0; Y'_1 | X; Y_0; Y_1; X'; Y'_0; Y'_1 | …)</th></tr>
<tr><td>0</td><td>1/5</td><td>3;1;1;0;0;0 | 3;1;1;0;0;0 | 3;1;1;0;0;0 | 0;0;0;3;1;1 | 0;0;0;3;1;1 | 0;0;0;3;1;1</td></tr>
<tr><td>1</td><td>2/9</td><td>3;1;1;0;0;0 | 3;1;1;0;0;0 | 2;1;1;0;0;0 | 0;0;0;2;1;1 | 0;0;0;2;1;1 | 0;0;0;3;1;1</td></tr>
<tr><td>2</td><td>1/4</td><td>2;1;1;0;0;0 | 2;1;1;0;0;0 | 2;1;1;0;0;0 | 0;0;0;2;1;1 | 0;0;0;2;1;1 | 0;0;0;2;1;1</td></tr>
<tr><td>3</td><td>2/7</td><td>1;1;1;0;0;0 | 2;1;1;0;0;0 | 2;1;1;0;0;0 | 0;0;0;2;1;1 | 0;0;0;1;1;1 | 0;0;0;1;1;1</td></tr>
<tr><td>4</td><td>1/3</td><td>2;1;0;0;0;0 | 2;1;0;0;0;0 | 2;1;0;0;0;0 | 0;0;0;2;1;0 | 0;0;0;2;1;0 | 0;0;0;2;1;0</td></tr>
<tr><td>5</td><td>2/5</td><td>1;1;1;0;0;0 | 1;1;1;0;0;0 | 1;0;1;0;0;0 | 0;0;0;1;1;1 | 0;0;0;1;1;1 | 0;0;0;1;0;1</td></tr>
<tr><td>6</td><td>1/2</td><td>1;1;0;0;0;0 | 1;1;0;0;0;0 | 1;1;0;0;0;0 | 0;0;0;1;1;0 | 0;0;0;1;1;0 | 0;0;0;1;1;0</td></tr>
<tr><td>7</td><td>2/3</td><td>1;0;0;0;0;0 | 1;0;1;0;0;0 | 1;0;1;0;0;0 | 0;0;0;1;0;0 | 0;0;0;1;0;1 | 0;0;0;1;0;1</td></tr>
<tr><td>8</td><td>3/4</td><td>1;0;1;0;0;0 | 1;0;1;0;0;0 | 1;0;1;0;0;0 | 0;0;0;1;0;1 | 0;0;0;1;0;1 | 0;0;0;1;0;1</td></tr>
</table>

For each rate, the puncturing table shall be read first from left to right and then from top to bottom.

3.6 CRC

The 32 bit ITU-T V.42 {RD-5} polynomial 0x04C11DB7 CRC is appended to the last segment of the datagram. The CRC is calculated over all fragments of the datagram.

$F(x) = x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^{8} + x^{7} + x^{5} + x^{4} + x^{2} + x + 1$

Initial state: 0xFFFFFFFF

1488146939The bit mapping is shown in figures Figs. A3-1159 to , A103-2 and A3-3119.

3 The baseband shall employ a root raised cosine filter.

FIGURE A1-15

QPSK symbol to bit mapping

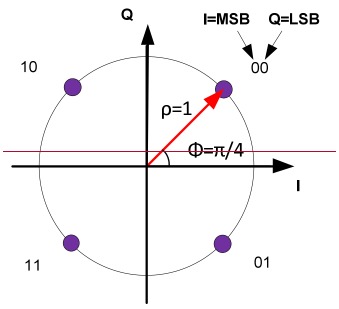
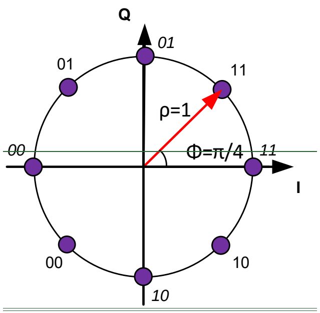


FIGURE A3-1916

Bit Mapping for π/4 QPSK



NOTE – Each subsequent transmission is phase-rotated by π/4.

FIGURE A3-107 [REMOVE]2

Bit Mapping for 8PSK (MSB left, LSB right)

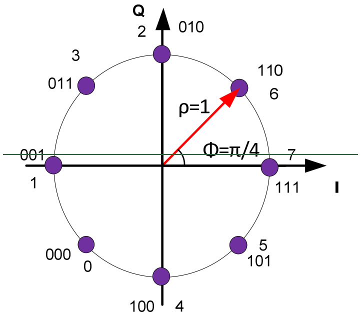


FIGURE A1-17

8PSK symbol to bit mapping

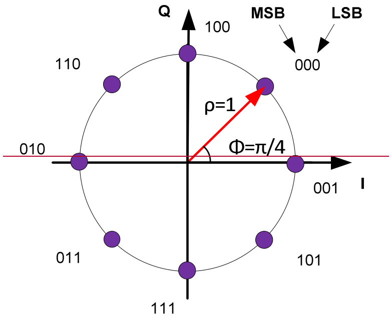


FIGURE A1183-3

Bit Mapping for 16QAM (MSB left, LSB right)

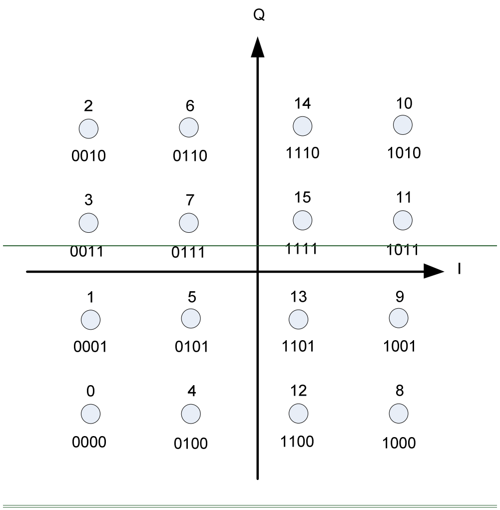
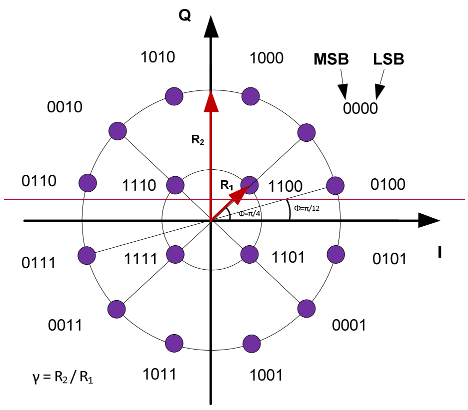


FIGURE A1-19

16APSK bit to symbol mapping



The 16 APSK modulation constellation is composed of two concentric rings of uniformly spaced 4 and 12 PSK points, respectively in the inner ring of radius R_1 and outer ring of radius R_2.

The ratio of the outer circle radius to the inner circle radius ($\gamma = R_2/R_1$) shall be equal to 3. R_1 shall be set to $1/\sqrt{7}$, R_2 shall be set to $3/\sqrt{7}$ in order to have the average signal energy equal to 1.

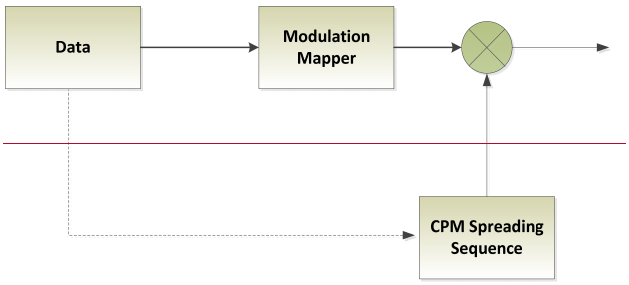
Similar to AIS, when data is output on the VHF data link it should be grouped in bytes of 8 bits from top to bottom of the table associated with each message in accordance with ISO/IEC 13239:2002. Each byte should be output with least significant bit first.

3.9.1 Spread spectrum with constant envelope

Direct sequence spreading with constant envelope can be implemented according to the spreading strategy {RD-3}. This provides a way to generate constant envelope signals whilst allowing the use of linear modulations (i.e. BPSK, or QPSK for data modulation). In this approach the CPM spreading sequences are selected such that the spread symbols maintain quasi continuous phase even at the transition from one symbol to the next. The CPM spreading principle is provided in Fig. A1-20.

FIGURE A1-20

CPM Spreading Principle



In order to avoid phase discontinuity at the data symbol transitions, the proposed solution is to adapt the spreading sequence to the modulation data. In other words, the CPM spreading sequence at the edge of each symbol is adapted according to the new input modulation symbol value to avoid any phase discontinuity. Such a solution produces a small loss at the receiver as the receiver does not know the edge symbol part of the used CPM spreading sequence. For a spreading factor of 16 or higher, the resulting correlation loss experienced by the receiver due to this issue is less than 0.25 dB. Performance losses with respect to conventional spreading is thus quite negligible provided that SF = 16 or larger is used.

The CPM spreading sequences are computed and optimized off line and then stored in the memory of the terminals and receivers. A single spreading code is sufficient for all the users in the system. There is thus no need for storing multiple spreading sequences but just a single spreading sequence.

The stored spreading sequence is then applied starting from the preamble and continuing in the data part (as shown in Fig. A1-21). It should be noted that the actual spreading sequence is actually partly dependent on the modulation symbols in order to ensure continuity of the signal phase when the modulation symbol changes (Fig. A1-20). The spread samples are computed on the basis of the current modulation symbol and previous modulation symbol. For QPSK modulation there are 4 possible values for the phase difference of these two symbols. An index from 0 to 3 can point to the possible phase differences and is used to address which of 4 possible spreading sequences is actually used for computing the output signal. Figure A1-22 illustrates the power spectral properties of the proposed modulation scheme (with spreading factor 16). Due to its constant envelope properties, this modulation scheme can operate with a transmit power amplifier operating close to saturation while maintaining a low power leakage to adjacent channels.

FIGURE A1-21

Proposed Spreading in the CPM

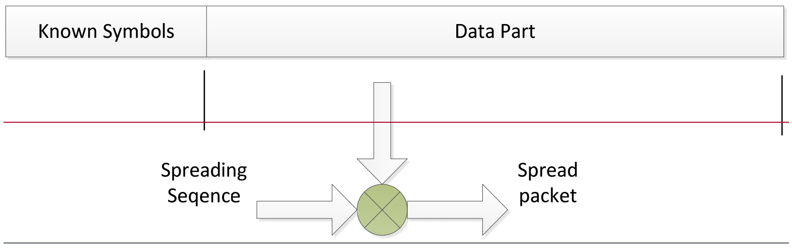
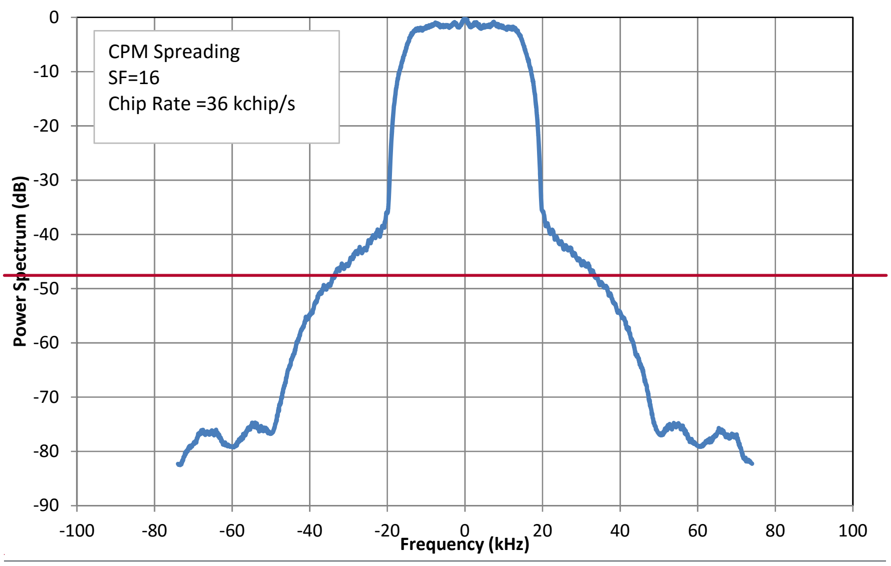


FIGURE A1-22

Power spectral properties of spread spectrum with constant envelope



3.107 Antenna configurations for VDES ship stations

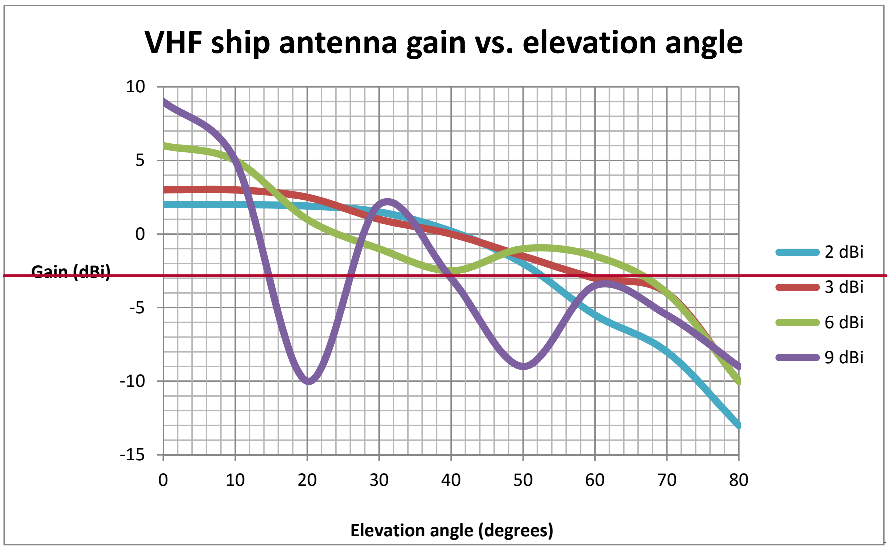
3.107.1 Antenna Gain

Existing ship antennas may be used for VDES. The maximum antenna gain for these antennas ranges from 2 dBi to 10 dBi. Representative antenna patterns are shown in Fig. A1-23126.

A ship antenna with a minimum gain at 0 degrees elevation of 3 dBi at the receiver input is required.

FIGURE A1-23126

Ship antenna gain vs. elevation angle



3.107.2 Received signal to noise plus interference level

The noise floor is a function of many sources such as vessel electronics, other radio equipment, power supplies, etc., and sensitivity is also reduced by RF cabling losses and the LNA noise figure. Table A1-7105 presents representative values for the receiver noise figure.

TABLE A1-7105

Ship receiver noise figure calculations

Antenna noise temperature*	245.0	K
LNA noise figure	6.0	dB
LNA noise temperature	813.8	K
Feed loss noise temp at LNA	0.0	K
Antenna noise temp at LNA	245.0	K
System noise temp at LNA	1058.8	K
System noise temp at LNA	30.2	dBK

* The galactic background antenna noise temperature is 245 K at 160 MHz {RD-4}.

3.118 Ship e.i.r.p. vs. elevation angle

The minimum ship e.i.r.p. vs elevation angle is shown in Table A1-1186. There are no minimum e.i.r.p. requirements above 80 degrees elevation. Table A1-1186 is based on a linear transmitter meeting the maximum Adjacent Channel Interference levels defined in Table A1-1297. For saturated operation the e.i.r.p. shall be 3 dB higher.

TABLE A1-1186

Minimum ship e.i.r.p. vs. elevation angle

Ship elevation angle	Ship antenna gain	Minimum ship e.i.r.p. with 6 W transmitter
degrees	dBi	dBW
0	3	10.8
10	3	10.8
20	2.5	10.3
30	1	8.8
40	0	7.8
50	−1.5	6.3
60	−3	4.8
70	−4	3.8
80	−10	−2.2
90	−20	−12.2

3.129 Transmitter requirements for VDES ship stations

3.129.1 Transmitter power

Table A1-1297 defines the requirements for the VDES ship station transmitters.

TABLE A1-1297

Transmitter parameters mobile station

Transmitter parameters	Requirements	Condition
Frequency error	3 ppm	normal
Transmit power	Transmit average power should be at least 1 watt and not exceed 25 watts as declared by the manufacturer. ±1.5 dB normal, +2/−6 dB extreme	Conducted
Maximum adjacent power levels for 25 kHz channel	0 dBc −25 dBc −60 dBc	Δ*fc* < ±12.5 kHz ±12.5 kHz < Δ*fc* < ±25 kHz ±25 kHz < Δ*fc* < ±75 kHz
Maximum adjacent power levels for 50 kHz channel	0 dBc −25 dBc −60 dBc	Δ*fc* < ±25 kHz ±25 kHz < Δ*fc* < ±50 kHz ±50 kHz< Δ*fc* < ±100 kHz
Maximum adjacent power levels for 100 kHz channel	0 dBc −25 dBc −60 dBc	Δ*fc* < ±50 kHz ±50 kHz < Δ*fc* < ±100 kHz ±100 kHz < Δ*fc* < ±150 kHz
Spurious emissions	−36 dBm −30 dBm	9 kHz to 1 GHz 1 GHz to 4 GHz

Commenté [SP68]: Action Item#20, change proposal ChangeProposal_Item20_RN_YM_v2_20160316.docx

3.130 Shutdown procedure

An automatic transmitter hardware shutdown procedure and indication should be provided in case a transmitter continues to transmit for more than 2 s. This shutdown procedure should be independent of software control.

3.141 Safety precautions

The VDES installation, when operating, should not be damaged by the effects of open circuited or short circuited antenna terminals.

4 Functions of the VDES

The VDES should support the following:

4.1 Automatic Identification System

The AIS will operate as defined by Recommendation ITU-R M.1371.

4.2 Application-Specific Messages – Annex 2

Annex 2 describes the characteristics of the ASM channel that will support applications specific messages in order to improve the efficiency of application specific message transmissions and to protect the original function of the AIS.

4.3 VDE terrestrial – Annex 3

Annex 3 describes the characteristics of the VDE terrestrial channels providing an efficient terrestrial data transfer link enabling a wide variety of applications for the maritime community.

4.4 VDE satellite downlink – Annex 4[VDESAT]

Annex 4 [VDESAT] describes the characteristics of a satellite downlink that will support multi-cast multi-package data transfers and shore originated unicast multi-package data transfers via satellite.

4.5 VDE satellite uplink – Annex 5

Annex 5 describes the characteristics of a satellite uplink that will support the collection of information from VDES stations and support long range ship-to-shore communications.

4.6 VDES sharing options – Annex 6

Annex 6 describes the characteristics necessary for each component of the VDES to share the available spectrum such that impact between services is minimized and AIS is respected.

4.7 VDES original design considerations – Annex 7

Annex 7 is an informative annex that provides additional information on the technical consideration of the VDES. It identifies aspects of both terrestrial and satellite VDE components, including access scheme options, antenna designs, and system sharing.

Annex 2

Technical characteristics of the Application Specific Message (ASM) channels for the VDES in the VHF maritime mobile band

1 Introduction

This section describes those elements of the ASM that are unique to ASM operation. It contains a description of the different protocols according to the OSI layer model and recommends implementation details for each layer. For those elements that are common, the cross reference into Annex 1 is provided.

The system should use TDMA techniques in a synchronized manner.

This Annex describes the characteristics of the TDMA access schemes which include random access TDMA (RATDMA), Multiple Incremental TDMA (MITDMA), fixed access TDMA (FATDMA), techniques. Slot carrier sense TDMA (SCTDMA) may be implemented as a option. The behavior should be in accordance with Recommendation ITU-R M.1371-5 Annex 7.

1 Structure of the application specific messages

This Annex describes the characteristics of the TDMA access schemes which include random access TDMA (RATDMA), incremental allocated TDMA (ITDMA), fixed access TDMA (FATDMA), and slot carrier sense TDMA (SCTDMA) techniques.

For application specific messages refer to Recommendation ITU-R M.1371 in general.

1.1 Specific responsibilities of the OSI layers as defined in Annex 1 for preparing ASM data for transmission

Refer to Annex 1.

1.1.1 Physical layer

Convert digital transmission packet to π/4 Quadrature Phase-Shift Keying (QPSK) signal to modulate transmitter.

1.1.2 Link layer

The link layer is divided into three sub-layers with the following tasks.

1.1.2.1 Link management entity

This sub layer has the following functions:

– Assemble ASM message bits
– Order the ASM message bits into 8-bit byte for assembly of transmission packet.

1.1.2.2 Data link services

This sub layer has the following functions:

– Calculate frame check sequence (FCS) of the ASM message bits (see § 3.2.2.3).
– Append FCS to ASM message to complete creation of transmission packet contents.
– Complete assembly of transmission packet.

1.1.2.3 Media access control

Media access control provides a method for granting access to the data transfer to the VHF data link (VDL). The method used is a TDMA scheme using a common time reference.

1.1.3 Network layer

The network layer is responsible for the management of priority assignments of messages, distribution of transmission packets between channels, and data link congestion resolution.

1.1.4 Transport layer

The transport layer is responsible for converting data into transmission packets of correct size and sequencing of data packets.

2 Physical layer

2.1 Parameters

2.1.1 General

The physical layer is responsible for the transfer of a bit-stream from an originator, out on to the data link. The performance requirements for the physical layer are summarized in Tables A2-1 to A2-3.

The low setting and the high setting for each parameter is independent of the other parameters.

TABLE A2-1

Minimum required time division multiple access transmitter characteristics

Parameter name	Units	Low setting	High setting
Channel spacing (encoded according to RR Appendix 18 with footnotes)(1)	kHz	25	25
ASM 1 (2027)(1)	MHz	161.950	161.950
ASM 2 (2028)(1)	MHz	162.000	162.000
Transmit output power	W	1	12.5

(1) See Recommendation ITU-R M.1084, Annex 4.

2.1.2 Transmission media

Data transmissions are made in the VHF maritime mobile band. Data transmissions should use ASM 1 and/or ASM 2 channels.

2.1.3 Multi-channel operation

The ASM station should be capable of receiving on two parallel channels and transmitting on two independent channels. Two separate TDMA receiving processes should be used to simultaneously receive on two independent frequency channels. One TDMA transmitter may be used to enable TDMA transmissions on one orof two independent frequency channels.

ASM transmission should alternate between the two ASM channels ~~be sent on one of the ASM channels. Each new ASM transmission should switch to the ASM channel not used in the previous transmission.~~

~~ITDMAATDMA~~ MITDMA linked transmissions should be on the same channel.

2.2 Transceiver characteristics

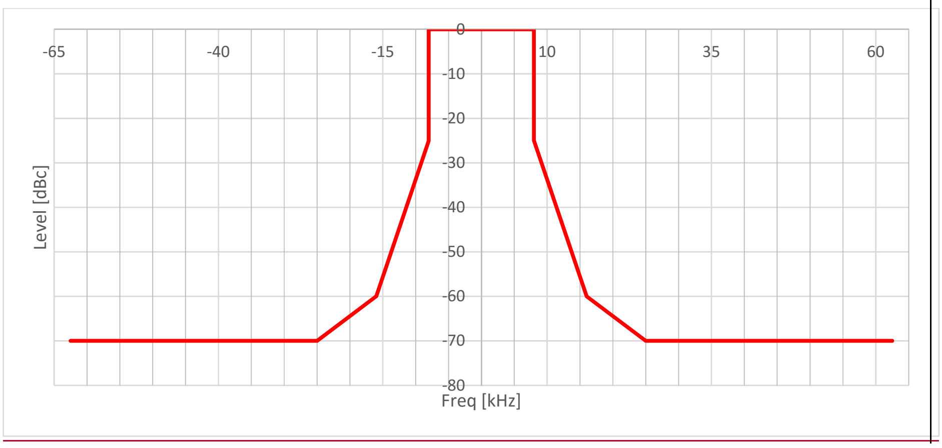
The transceiver should perform in accordance with the characteristics set forth herein, see TABLE A2-2 and FIGURE A2-1a. The resolution bandwidth for the mask measurement is 300Hz.

TABLE A2-2

Minimum required time division multiple access transmitter characteristics

Transmitter parameters	Requirements
Carrier power error	±1.5 dB
Carrier frequency error	± 500 Hz
Slotted modulation mask	Δ*fc* < ±8 kHz: 0 dBc ±8 kHz < Δ*fc* < ±16 kHz: below the straight line between −25 dBc at ±8 kHz and −60 dBc at ±16 kHz ±16 kHz < Δ*fc* < ±25 kHz: below the straight line between −60 dBc at ±16 kHz and −70 dBc at ±25 kHz ±25 kHz < Δ*fc* < ±62.5 kHz: −70 dBc ~~Δfc < ±10 kHz: 0 dBc~~ ~~±10 kHz < Δfc < ±25 kHz: below the straight line between −25 dBc at ±10 kHz and −70 dBc at ±25 kHz~~ ~~±25 kHz < Δfc < ±62.5 kHz: −70 dBc~~
Spurious emissions	~~−36~~ 36 dBm: 9 kHz ... ~~1~~ 1 GHz ~~−30~~ 30 dBm: 1 GHz ... 4 GHz

FIGURE A2-1a ASM Slotted modulation mask



Commenté [B69]: Diagram needed

Commenté [B70]: This is changed for the protection of AIS satellite reception

Commenté [SP71]: The modulation shall fit into the mask; changed in order to protect AIS receiption by ships and satellites

Commenté [SP72]: Action Item#20, change proposal ChangeProposal_Item20_RN_YM_v2_20160316.docx

TABLE A2-3

Minimum required time division multiple access receiver characteristics without FEC

Receiver parameters	Requirements
Sensitivity	20% PER @ −107 dBm
Error behaviour at high input levels	1% PER @ −77 dBm 1% PER @ −7 dBm
Adjacent channel selectivity	20% PER @ 70 dB
Spurious response rejection	20% PER @ 70 dB
Intermodulation response rejection	20% PER @ 74 dB
Spurious emissions	−57 dBm (9 kHz to 1 GHz) −47 dBm (1 GHz to 4 GHz)
Blocking	20% PER @ 86 dB

2.3 Modulation scheme

The base modulation scheme is defined by the Link Configuration Idπ/4 Quadrature Phase Shift Keying (QPSK).MCS-0, see Table [x]A1-6. Multiple modulation schemes MCS-1, 2, …, 15 can be added in the future.

Commenté [JC73]: Confirm ref

For the modulation bit mapping, see Annex 1.

2.3.1 π/4 Quadrature Phase-Shift Keying (π/4 QPSK)

The modulator transmitter roll off used for transmission of data should be maximum 0.35 (highest nominal value).

The demodulator used for receiving of data should be designed for a receiver roll off of maximum 0.35 (highest nominal value).

2.3.42 Frequency stability

The frequency stability of the VHF radio transmitter/receiver should be ±500 Hz or better.

2.45 Data transmission bit rate

The transmission bit rate should be 19.2 kbit/s ±10 ppm for π/4 QPSK.

2.56 Frame structure

For the generic definition of the frame structure, see Annex 1, § 3.3.

2.5 Training sequence

The training sequence is 1111110011010100000110010100 (28 bits)111111001101010000011001010.

2.67 Signal information

Signal information selects the modulation scheme and coding according to the Link Configuration Id defined in Table A1-6

The signal information should follow the training sequence.

The signal information consists of 4 bits encoded into a sequence of 7 bits using Hamming (7,4) code. The signal information selects the modulation and coding schemes are used and allows for adding new modulation and coding schemes in the future.

Signal information "XXXX" – selects the modulation scheme and coding according to the Link Configuration Id MCS defined in Table [x]A1-5.1[TBD].:

2.78 Data encoding

Data coding is not used.

2.898 Forward error correction and Bit Scrambling

When forward error correction is used, it will be used as defined in Annex 1. Interleaving and bit scrambling are used, as defined by the FEC designated in the signal information. In the event of no FEC, bit scrambling according to Annex 1 shall be implemented.

2.9109 Transmitter transient response

2.9.1 Switching time

The time taken to switch from transmit to receive conditions, and receive to transmit conditions, should not exceed the transmit transmit ramp up and ramp down attack or release time, see Annex 1; 5.2.3.1. It should be possible to receive a message from the slot directly after or before own transmission.

The equipment should not be able to transmit during channel switching operation.

2.10101 Transmitter power

The power level is determined by the link management entity (LME) of the link layer.

2.10101.1 Provision should be made for two levels of nominal power (high power, low power) as required by some applications. The default operation of the ASM station should be on the high nominal power level.

2.10101.2 The nominal levels for the two power settings should be 1 W (PEP) and 12.5 W (average power); tolerance should be within ±1.5 dB.

3 Link layer

The link layer specifies how data is packaged in order to apply error detection and correction to the data transfer. The link layer is divided into three sub-layers.

3.1 Sub-layer 1 – medium access control

The medium access control (MAC) sub layer provides a method for granting access to the data transfer medium, i.e. the VHF data link. The access scheme is TDMA using a common time reference.

3.1.1 TDMA synchronization

TDMA synchronization is achieved using an algorithm based on a synchronization state as described below. The sync state flag within the ITDMAATDMA MITDMA communication state indicates the synchronization state of a station.

The TDMA receiving process should not depend be synchronized onto slot boundaries.

Synchronization other than UTC direct may be provided by the AIS system.

Commenté [JC74]: Confirm ref

Commenté [SP75]: Add a reference here to where these times are defined.

3.1.1.1 Coordinated universal time direct

A station, which has direct access to coordinated universal time (UTC) timing, with the required accuracy, should indicate this by setting its synchronization state to UTC direct.

3.1.1.2 Coordinated universal time indirect

A station, which is unable to get direct access to UTC, but has access to the AIS system, may get its synchronization from the AIS system. It should then change its synchronization state to indicate the type of synchronization which is being provided by the AIS system.

3.1.2 Time division

The slot and frame are as defined in Annex 1. Access to the data link is, by default, given at the start of a slot. The frame start and stop coincide with the UTC minute, when UTC is unavailable the AIS system may provide the frame synchronization.

3.1.3 Slot phase and frame synchronization

Slot phase synchronization and frame synchronization is done by using information from UTC or from the AIS system.

3.1.3.1 Slot phase synchronization

Slot phase synchronization is the method whereby the slot boundary is synchronized with a high level of synchronization stability, thereby ensuring no message boundary overlapping or corruption of messages.

3.1.3.2 Frame synchronization

Frame synchronization is the method whereby the current slot number for the frame is known.

3.1.4 Slot identification

Each slot is identified by its index (0-2249). Slot zero (0) should be defined as the start of the frame.

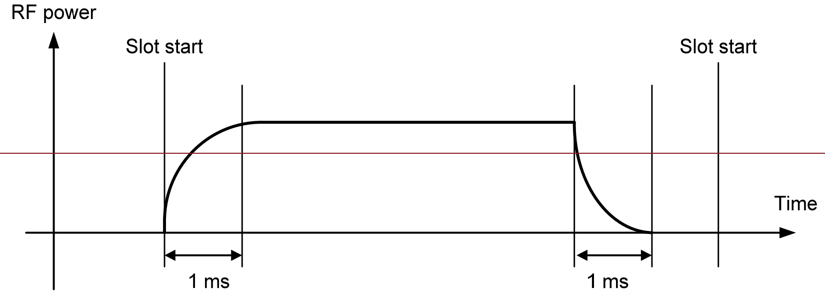
3.1.5 Slot access

The transmitter should begin transmission by turning on the RF power at slot start.

The transmitter should be turned off after the last bit of the transmission packet has left the transmitting unit. This event must occur within the slots allocated for own transmission. ~~The default length of a transmission occupies one (1) slot.~~ The slot access is performed as described in Annex 1 § 3.3~~shown in Fig. A2-1.~~.5.2.2.

Figure A2-1

Slot Access



3.1.6 Slot state

Each slot on an ASM channel can be in one of the following states:

– Free: meaning that the slot is unused on the channel within the receiving range of the own station for AIS/ASM/VDE

– Internal allocation: meaning that the slot is allocated by own station for the purpose of AIS/ASM/VDE/long range transmission

– [available] External allocation by a mobile station: meaning that the slot is allocated for the purpose of ASM transmission by another station.

- [unavailable: external allocation by a base station, TBD] AIS Available –externally allocated by an AIS which may be considered as a candidate slot

– AIS Unavailable –externally allocated by an AIS which should not be considered as a candidate slot for the following reasons:

SOTDMA slot timeout = 0

FATDMA allocated slot

– ASM Unavailable – Externally allocated by an ASM station within the receiving range of the own station

– VDE Unavailable – slots allocated to own station for VDE reception

3.2 Sub layer 2 – data link service

The data link service (DLS) sub layer provides methods for:

– data link activation and release;

– data transfer; or

– error detection, correction and control.

3.2.1 Data link activation and release

Based on the MAC sub layer the DLS will listen, activate or release the data link. A slot, marked as free or externally allocated, indicates that own equipment should be in receive mode and listen for other data link users.

3.2.2 Data transfer

Data transfer should use a bit-oriented protocol and should be in accordance with this standard.

3.2.2.1 Packet format

Data is transferred using thea generic transmission packet as defined in Annex 1 § 3.3 and as shown in Fig. A12-542:

Figure A2-2

Packet Format

Ramp-up	Training sequence	Signal information	Data Length	Data	CRC	Buffer
16	2728	7	10	380 (Maximum)	32	40

The packet should be sent from left to right. The training sequence should is be used in order to synchronize the VHF VDES receiver. The total length of the default packet is 256 symbols (512 bits, (π/4 QPSK).

3.2.2.2 Ramp-up

The ramp-up portion of the waveform provides for a gradual transition to transmission state from transmitter off state. A gradual ramp-up period provides important spectral shaping to reduce energy spread outside the desired signal modulation bandwidth, and reduces interference to other users of the current and adjacent channel.

3.2.2.3 Frame check sequence

The FCS uses the cyclic redundancy check, see § 3.2.3.

3.2.2.4 Buffer

The buffer is 40 bits long and should be used as follows:

– distance delay: 28 bits

– synchronization jitter: 12 bits

The distance delay should provide protection for a propagation range of approximately 222.24 km (120 NM)[4].

3.2.2.52 Summary of the default transmission packet

The data packet is defined in Table A2-4.

The ASM channel configurations MCS aare defined byin Link Configuration Id table, see Table [x]A1-5.1[TBD].

Commenté [JC76]: Confirm ref

[4] 1 Nautical mile = 1 852 metres.

TABLE A2-4

PSingle slot packet symbolbit structure for π/4 QPSK modulation scheme

		Description
Ramp up	84 symbols16 bits	
Training sequence	27 symbols27 bits	Necessary for synchronization
Link configuration idSignal information/MCS/FEC	16 symbols 7 bits	Decoded from (32,6) biorthogonal code[Hamming (167,46)] ASM channel configurations as defined in Link Configuration Id table0000 – no codingMCS-0 0001 – MCS-1 ... 1111 – MCS-15 1/2 code rate 0010 – 3/4 code rate 0011 – 5/6 code rate
Data length	10 bits	Default: "0110011100" (412) encoded data and CRC;
Data	1 slot: 17692 2 slot: 432 3 slot:-96886044 symbols 380 bits	The symbol count and the information bits Without encoding: 380 bits With encoding: varies according to coding rate as defined in theby the link configuration id Signal Information field
CRC	16 symbols 32 bits	The CRC only includes the Without encoding: 32 bits; With encoding: varies according to coding rate defined in the Signal Information field; Only the data length and data field are included in the CRC
Ramp Down	4 symbols	Distance delay and jitter
Guard TimeBuffer	1313 symbols 40 bits	Distance delay and jitter
Total	1 slot: 256 2 slot: 512 3 slot:— 768 1024 symbols 512 bits	Maximum 512 bits for 19.2 kbits/s π/4 QPSK

3.2.2.63 Transmission timing

There should be no modulation may be applied during the ramp down up period, but it shall not be considered as part of the training sequence.

3.2.2.74 Long transmission packets

A station may occupy a maximum of 354 consecutive slots, as defined by the Link Configuration id, for one (1) continuous transmission. Only a single application of the overhead (ramp up, training sequence, flags, FCS, bufferguard time) is required for a long transmission packet. The length of a long transmission packet should not be longer than necessary to transfer the data; i.e. the ASM should not add filler, however necessary block coding sizes and/or data fill to byte boundaries is permitted.

Commenté [JC77]: Comment on consistency – ID, Id or id?

3.2.3 Error detection and control

Error detection is accomplished using a CRC polynomial as described in Annex 1.

3.2.4 Forward Error correction

Forward error correction should be handled as described in Annex 1, and specified by the Link Configuration Id see Table A1-6signal information.

3.3 Sub layer 3 – link management entity

The LME controls the operation of the DLS, MAC and the physical layer.

3.3.1 Access to the data link

There should be different access schemes for controlling access to the data transfer medium. The application and mode of operation determine the access scheme to be used.

The access schemes are ITDMAATDMA MITDMA, RATDMA, SCTDMA and FATDMA.; [MITDMAATDMA].

3.3.1.1 Cooperation on the data link

The access schemes operate continuously, and in parallel, on the same physical data link. They all conform to the rules set up by the TDMA. The ASM system must give priority to the AIS system when accessing the physical data link.

3.3.1.2 Candidate slots

Slots, used for transmission, are selected from *candidate slots* in the selection interval (SI) which is defined as 150 300 slots.

The selection process uses received data from AIS, and ASM and VDE.

There should be, at minimum, a set of four eight candidate slots to choose from.

The candidate slots are primarily selected from slots that are free on AIS, and ASM and VDE.

The available AIS slots are as defined in Recommendation ITU-R M.1371 and must only be taken from the most distant station(s) within the SI.

If the candidate slot set contains less than four eight slots, additional candidate slots can be obtained by using the following rules and order (rule 1 followed by rule 2):

Rule 1: available slot on onean AIS channel and free on the otherall other AIS and free on the ASM and [+ VDE] channels

Rule 2: available slot on both AIS channels (AIS1 and AIS2) and free on all ASM and [+ VDE] channels.

[Rule 3: available on AIS channels and available on ASM channels]

When selecting candidates for messages longer than one (1) slot, a candidate slot should be the first slot in a consecutive block of slots that conform to the selection criteria stated above.

If the station cannot find sufficient number of candidate slots, the station should not transmit and should re-schedule the transmission.

The candidate slot selection process also has to consider time periods reserved for the reception of the bulletin board.

The purpose of maintaining a minimum of four eight candidate slots within the same probability of being used for transmission is to provide high probability of access to the link.

Note that the [AIS and VDE channels need only to be considered when ASM and the other system shareAIS are using the same antenna]. Or when there is not [sufficient isolation] to support independent operations such that the AIS station will still meet its receiver performance requirements.

Commenté [JC78]: From Peggy - Task item 154

3.3.2 Modes of operation

There should be twohree modes of operation, autonomous and assigned. The default mode should be autonomous and may be switched to/from other modes.

3.3.2.1 Autonomous

A station operating autonomously should determine its own schedule for transmission. The station should automatically resolve scheduling conflicts with other stations.

3.3.2.2 Assigned

A station operating in the assigned mode takes into account the transmission schedule of the assigning message when determining when it should transmit.

3.3.2.3 Polled

A station operating in polled mode should automatically respond to interrogation messages. Operation in the polled mode should not conflict with operation in the other two modes. The response should be transmitted on the channel where the interrogation message was received.

3.3.3 Initialization

At power on, a station should monitor the TDMA channels for one (1) minute to determine channel activity, other participating member IDs, current slot assignments, and possible existence of shore stations. During this time period, a dynamic directory of all stations operating in the system should be established. A frame map should be constructed, which reflects TDMA channel activity. After one (1) minute has elapsed, the station may be available to transmit ASM messages according to its own schedule.

3.3.43 Channel access schemes

The access schemes, as defined below, should coexist and operate simultaneously on the TDMA channel. The access schemes ITDMAATDMAATDMA, RATDMA and FATDMA are is as defined in Recommendation ITU-R M.1371.[and new MITDMA]

3.3.3.1 Multiple incremental time division multiple access (MITDMA)

The MITDMA access schemes allows a station to pre-announce transmission slots that the station will use in the future. A single MITDMA transmission may be used to schedule up to three future transmissions with each transmission occupying up to 3 slots.

3.3.3.1.1 Multiple incremental time division multiple access algorithm

The first transmission within a MITDMA chain will be a single slot transmission using RATDMA access. Prior to the first transmission the station will randomly select up to three additional transmission slots. The offset from the first transmission to the first future transmission is calculated and provided in the MITDMA communication state. If a second future transmission is desired, then the offset from the first future transmission to the second future transmission is provided in the MITDMA communication states. If a third future allocation is desired, then the offset from the second future transmission to the third future transmission is provided in the MITDMA communication state.

Receiving stations should mark these slot allocations as unavailable.

MITDMA may chain up to 15 transmissions together in a single frame.

3.3.3.2 Random access time division multiple access (RATDMA)

RATDMA is used when a station needs to allocate a slot, which has not been pre-announced. This is generally done for the first transmission slot during MITDMA chain, or for messages of a non-repeatable character.

3.3.3.2.1 Random access time division multiple access algorithm

The RATDMA access scheme should use a probability persistent (p-persistent) algorithm as described in this paragraph (see Table A2-4).

When a candidate slot is selected, the station randomly select a probability value (LME.RTP1) between 0 and 100. This value should be compared with the current probability for transmission (LME.RTP2). If LME.RTP1 is equal to, or less than LME.RTP2, transmission should occur in the candidate slot. If not, LME.RTP2 should be incremented with a probability increment (LME.RTPI) and the station should wait for the next candidate slot in the frame.

The SI for RATDMA should be 300 time slots, which is equivalent to 8 s. The candidate slot set should be chosen within the SI, so that the transmission occurs within 8 s.

Each time that a candidate slot is entered, the p-persistent algorithm is applied. If the algorithm determines that a transmission shall be inhibited, then the parameter LME.RTCSC is decremented by one and LME.RTA is incremented by one.

LME.RTCSC can also be decremented as a result of another station allocating a slot in the candidate set. If LME.RTCSC + LME.RTA < 8 then the candidate set shall be complemented with a new slot within the range of the current slot and LME.RTES following the slot selection criteria.

3.3.3.2.2 Random access time division multiple access parameters

The following parameter are used to control the RATDMA scheduling:

TABLE A2-4

Commenté [JC79]: Table numbering to be reviewed post intersessional

RATDMA Paramenters

Symbol	Name	Description	Minimum	Maximum
RTCSC	Candidate slot counter	The number of slots currently available in the candidate set. NOTE 1 – The initial value is always 8 or more (see § 3.3.1.2). However, during the cycle of the p-persistent algorithm the value may be reduced below 8	1	300
RTES	End Slot	Defined as the slot number of the last slot in the initial SI, which is 150 slots ahead	0	2249
RTPS	Start probability	Each time a new message is due for transmission, LME.RTP2 should be set equal to LME.RTPS. LME.RTPS shall be equal to 100/LME.RTCSC. NOTE 2 – LME.RTCSC is set to 8 or more initially. Therefore LME.RTPS has a maximum value of −25 (100/8)	0	25
RTP1	Derived probability	Calculated probability for transmission in the next candidate slot. It should be less than or equal to LME.RTP2 for transmission to occur, and it should be randomly selected for each transmission attempt	0	100
RTP2	Current probability	The current probability that a transmission will occur in the next candidate slot	RTPS	100
RTA	Number of attempts	Initial value set to 0. This value is incremented by one each time the p-persistent algorithm determines that a transmission shall not occur	0	149
RTPI	Probability Increment	Each time the algorithm determines that transmission should not occur, LME.RTP2 should be incremented with LME.RTPI. LME.RTPI shall be equal to(100 – LME.RTP2)/LME.RTCSC	1	25

3.3.4.1 Slot carrier sense time division multiple access (SCTDMA)

SCTDMA may be used for satellite-uplink transmissions.

3.3.4.2 Slot carrier sense time division multiple access algorithm

Access to the data link should be achieved with reference to frame start using UTC direct.

VDES stations using SCTDMA should detect if the slot is used by examining the CS detection window of 11 symbols [1 146 µs] starting at 4 symbols [833417 µs] and ending at 15 symbols [1 979 µs] after the start of the slot intended for transmission (T_0). Signals within the first 4 symbols

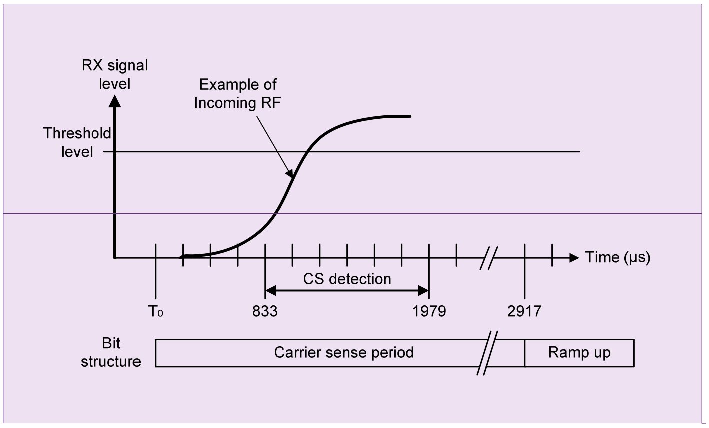
~~[833~~ 417 ~~µs] of the time period are excluded from the decision to allow for propagation delays and ramp down periods of other units.~~

~~VDES stations using the SCTDMA access scheme should not transmit on any slot in which, during the CS detection window, a signal level greater than the "CS detection threshold" is detected.~~

~~The transmission of a SCTDMA packet should commence~~ at symbol 28 ~~[2 917~~2501 ~~µs] after the nominal start of the time period (see Fig. A2-3).~~

~~FIGURE A2-~~13

~~Carrier sense timing~~



Commenté [B80]: change 833 to 417

~~3.3.4.3 Carrier sense detection threshold~~

~~The carrier sense (CS) detection threshold should be determined over a rolling 60 s interval on each Rx channel separately. The threshold should be determined by measuring the minimum energy level (representing the background noise) plus an offset of 10 dB. The minimum CS detection threshold should be −107 dBm and background noise should be tracked for a range of at least 30 dB (which results in a maximum threshold level of −77 dBm)[5].~~

3.3.34.43 Network access and entry of a new data stream

~~For ITDMA and RATDMA at~~At power on, a station should monitor the TDMA channels for one (1) min ~~interval~~ to determine channel activity, other participating member IDs, current slot assignments and reported positions of other users, and possible existence of base stations, as shown in Figure~~.~~ A2-~~4~~21. During this time ~~period~~, a dynamic directory of all members operating in the system should be established. A frame map should be constructed, which reflects TDMA channel activity. After one (1) minute has elapsed, the station may be available to transmit ASM messages according to its own schedule.

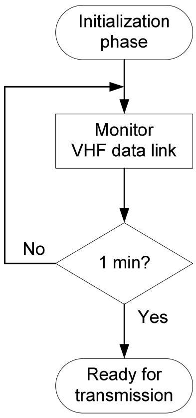
~~[5] The following example is compliant with the requirement:~~

~~– Sample the RF signal strength at a rate > 1 kHz, average the samples over a sliding 20 ms period and over a 4 s interval determine the minimum period value. Maintain a history of 15 such intervals. The minimum of all 15 intervals is the background level. Add a fixed 10 dB offset to give the CS detection threshold.~~

FIGURE A2-12

Network Access for MITDMA and RATDMA 4

Network Access for ITDMA MITDMA and RATDMA



3.3.3.4 RATDMA channel access

When the ASM station needs to transmit a single ASM message which is not repeated periodicly, it should use RATDMA access.

3.3.3.5 MITDMA channel access

When the ASM station needs to transmit a block of ASM messages, or if it needs to transmit ASM message perodically, it should use MITDMA access.

3.3.4.5 Priority of transmissions

There are 3(three4 (four) levels of message priority:

[Priority 1 (highest): Critical link management messages]

Priority 2: Safety related messages

Priority 3: Interrogation and responses to interrogation

Priority 34 (lowest): All other messages.

3.3.45 Message structure

The messages should have the following structure shown in Figure. A2-5 32 inside the data portion of a data packet.

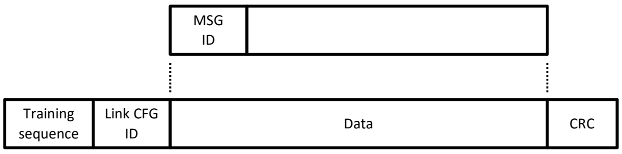
Commenté [B81]: may not be needed when link layer is defined, change 133

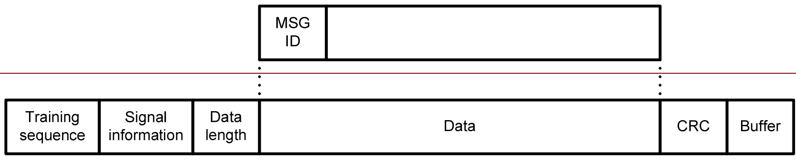
FIGURE A2-32

Message Structure

5

Message Structure





Each message is described using a table with parameter fields listed from top to bottom. Each parameter field is defined with the most significant bit first.

Parameter fields containing sub-fields (e.g. communication state) are defined in separate tables with sub-fields listed top to bottom, with the most significant bit first within each sub-field.

Character strings are presented left to right most significant bit first. All unused characters should be represented by the @ symbol, and they should be placed at the end of the string.

When data is output on the VHF data link it should be grouped in bytes of 8 bits from top to bottom of the table associated with each message. Each byte should be outputted with least significant bit first.

Shall be delete when change log 117 is done: A generic example for a message table is provided in Table A2-5.

TABLE A2-5

Generic Message Table

Parameter	Symbol	Number of bits	Description
P1	T	6	Parameter 1
P2	D	1	Parameter 2
P3	I	1	Parameter 3
P4	M	27	Parameter 4
P5	N	2	Parameter 5
Unused	0	3	Unused bits

The logical view of data is provided in Table A2-6.

TABLE A2-6

Logical view of data

Bit order	M---L--	M-------	--------	--------	--LML000
Symbol	TTTTTTDI	MMMMMMMM	MMMMMMMM	MMMMMMMM	MMMMNN000
Byte order	1	2	3	4	5

The output order to VHF data link is provided in Table A2-7.

TABLE A2-7

Output order to VHF data link

Bit order	--L---M	-------M	--------	--------	000LML--
Symbol	IDTTTTTT	MMMMMMMM	MMMMMMMM	MMMMMMMM	000NNMMM
Byte order	1	2	3	4	5

3.3.45.1 Message identification (see change log 133)

The message ID should be 6 4 bits long and should have a range of 0 – 16. The message ID should identify the message type. respect the current definitions of message IDs as defined for AIS in Recommendation ITU-R M.1371.

3.3.4.2. User identification

The user ID should be a unique identifier and is 30 bits long. All ASM messages will contain the user identifier to identify the source of the transmission.

3.3.45.23 Incremental time division multiple access message structure

The ITDMA message structure supplies the necessary information in order to operate in accordance with Recommendation ITU-R M.1371. The MITDMA message structure is shown in Figure. A2-643.

Commenté [JC82]: where is table referenced in text?

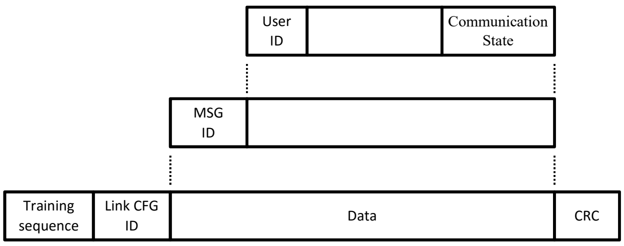
Commenté [JC83]: Where is table referenced in text?

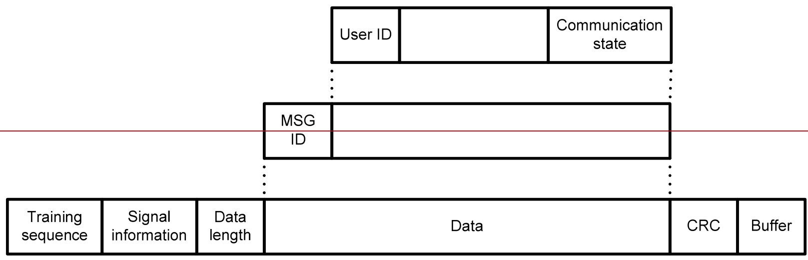
Commenté [JC84]: Confirm MITDMA? ITDMA? (text and figure disagree, text for 3.3.4 is also MITDMA

FIGURE A2-436

ATDMA Message Structure

ITDMAATDMA MESSAGE STRUCTURE





3.3.5.2.1 User identification

The user ID should be a unique identifier and is 30 bits long.

3.3.45.23.2-1 Multiple Incremental time division multiple access communication state

The communication state provides the following functions:

– it contains information used by the slot allocation algorithm in the ITDMA MITDMA concept.

; The MITDMA communication state is structured as shown in Table A2-55.

TABLE A2-5

MITDMA communication state parameters

Parameter	Number of bits	Description	Minimum	Maximum
Transmit block counter	4	A decrementing counter used to indicate how many transmissions are left to transmit within the chain A value of 1 indicates this is the last transmission within the chain A value of 0 indicates a recurring transmission.	0	15
Block Identifier	4	This identifier uniquely identifies the block of data within the transmit chain. This identifier also maps to the acknowledgment for addressed messages.	0	15
Slot Increment 1	8	Offset to the next slot to be used, referenced to the current transmission start slot. A value of 0 indicates no additional slot allocations	20	255
Number of Slots 1	2	Indicates the number of consecutive slots, which are allocated, starting at the slot increment A value of 0 indicates the 8 bits from Slot Increment 1 become the MSB for the Slot Increment 2	0	3
Slot Increment 2	8	Offset to the next slot to be used, referenced to the slot specified by slot increment 1 (or current transmission slot if the Number of Slots 1 is set to 0) A value of 0 indicates no additional slot allocations	20	255 45001
Number of Slots 2	2	Indicates the number of consecutive slots, which are allocated, starting at the slot increment	1	3
Slot Increment 3	8	Offset to the next slot to be used, referenced to the slot specified by Slot Increment 2	20	255
Number of Slots 3	2	Indicates the number of consecutive slots, which are allocated, starting at the slot increment	1	3
Total bits	37			
Note 1: When combining Slot Increment 1 and Slot Increment 2 as a 16 bit field. This value should not exceed 2 frames.				

– it also indicates the synchronization state.

The ITDMA communication state is structured as defined in Recommendation ITU-R M.1371. The ITDMA communication state should apply only to the slot in the channel where the relevant transmission occurs. ASM 1 and ASM 2 are independent channels.

4 Network layer

Commenté [B85]: together with link layer definition, change log 133

The network layer should be used for:

– Establishing and maintaining channel connections

– Management and priority assignments of messages

– Distribution of transmission packets between channels

– Data link congestion resolution.

4.1 Multi-channel operations

Two frequencies have been designated in RR Appendix 18 for ASM transmissions. These frequencies are:

– ASM1 (Channel 2027, 161.950 MHz)

– ASM2 (Channel 2028, 162.000 MHz)

Channel access is performed independently on each of the two channels. Generally, ASM transmission should alternate between the two channels when available.

Terrestrial transmissions of acknowledgements to addressed messages should be done on the channel as the initial message was received.

Chained transmissions using MITDMA shall all be done on the same channel.

4.2 Management of priority assignment for messages

ASM messages support message priority. The priority of the message is determined by the PI interface. The messages are serviced in order of priority. Messages with the same priority are dealt with in a FIFO order.

4.3 Data link congestion resolution

As the data link becomes loaded, the availability of transmission slots will reduce. When the data link is loaded to such a level as reception of ASM message`s is jeopardized, measures should be taken to reduce the loading.

ASM channel loading shall be measured independently per channel over a window of the past 2250 slots (1 Minute).

The amount of ASM transmissions on a specific channel shall be adopted to the channel loading on that channel.

The maximum number of slots allocated by one station on one channel shall not exceed 50 slots over a period of one minute. (2.2% duty cycle)

4.3.31 Mandatory quiet times

After the completion of a singular Non-MITDMA ASM channel transmission or a complete MITDMA transmission block chain, the ASM station shall wait for a specific time before additional transmission can be scheduled. This time is referred to as Quiet Time. The Selection Interval for finding candidate transmission slots starts after the Quiet Time.

For a singular transmission, Quiet Time shall per default be one second per timeslot.

For an MITDMA linked transmission chain, the Quiete Time is a function of the number of transmission slots within that chain. The Quiet Time shall be increased by one second per time slot used in the transmission chain.

The Quiet Time shall be increased with a multiplier, depending on channel load (Table A2-6)

Table A2-6

Quiet Time Multiplier.:

Channel load	<10%	10%-30%	30%<
Multiplier	1	2	3
Quiete Time [seconds] = Transmission slots * Multiplier			

Quiete Time [seconds] = Transmission slots * Multiplier

5 Transport layer

Commenté [B86]: together with link layer definition, chang log 133

The transport layer is responsible for:

– converting data into transmission packets of correct size;
– sequencing of data packets;
– interfacing protocol to upper layers.

The interface between the transport layer and higher layers should be performed by the presentation interface.

5.1 Definition of transmission packet

A transmission packet is an internal representation of some information which can ultimately be communicated to external systems. The transmission packet is dimensioned so that it conforms to the rules of data transfer. Transmission packets are fixed block sizes on slot boundaries with a maximum of 3 consecutive slots. When data does complety fill the block, then padding bits with the value of 0 should be added to completely required block size.

5.2 ASM identifier

Addressed and broadcast binary messages should contain a 16-bit application identifier, structured as follows: (Table A2-7)

TABLE A2-76

ASM identifier parameters

Bit	Description
15-6	Designated area code (DAC). This code is based on the maritime identification digits (MID). Exceptions are 0 (test) and 1 (international). Although the length is 10 bits, the DAC codes equal to or above 1 000 are reserved for future use
5-0	Function identifier. The meaning should be determined by the authority which is responsible for the area given in the designated area code

Whereas the application identifier allows for regional applications, the application identifier should have the following special values for international compatibility.

5.32 Transmission packets

5.32.1 Addressed Messages

Addressed messages are point to point communications between VDES stations. Addressed messages may require an acknowledgment. When an acknowledgement is required and not received, the VDES stations may retransmit the message.

5.23.2 Broadcast messages

A broadcast message lacks a destination identifier ID. Therefore, receiving stations should not acknowledge a broadcast message up to 3 times.

5.32.3 Conversion to presentation interface messages

Each received transmission packet should be converted to a corresponding presentation interface message and presented in the order they were received regardless of message category. Applications utilizing the presentation interface should be responsible for their own sequencing numbering scheme, as required. For a mobile station, addressed messages should not be output to the presentation interface, if Ddestination User ID (destination MMSIunique identifier) is different to the ID of own station (own MMSIunique identifier).

5.32.4 Conversion of data into transmission packets

The transport layer should convert data, received from the presentation interface into transmission packets. If the data exceeds the maximum limit, then a negative acknowledgement should be returned on the PI

5.43 Presentation interface protocolMITDMA access

Data, which is to be transmitted by the station, should be input via the presentation interface; data, which is received by the station, should be output through the presentation interface. The formats and protocol used for this data stream are defined by IEC 61162 series.

When the length of the data requires more than 3 consecutive slots, then the data should be divided up into sub-groups of 3 slot packets and MITDMA should be used to chain the transmissions together. A total of 15 MITDMA transmissions may be chained together. If the data provided by the PI exceeds this limit, a negative acknowledgment should be provided on the PI.

If data transmissions are repetitive in nature, and have a transmit interval less than 2 frames (4 500 slots), then MITDMA should be used to maintain the link.

If multiple messages are queued for transmission, then MITDMA should be used to allocate slots for the additional messages.

When using MITDMA for addressed messages, the MITDMA will provide the return slot for the message acknowledgment as specified in Slot Increment 3 during block identifier 2, 1 or 0.

5.4.1 MITDMA access example

The first transmission (TX 1) of a MITDMA chain is always a single slot transmission.

Determine the candidate slots for the TX 1. Apply the RATDMA algorithm until transmit criteria is meet.

Before transmitting at TX 1, determine the candidate slots for up to three additional tranmissions. Randomly select the transmit slots from the candidate slot lists. Calculate the offsets for these future tranmissions. This information is provided in the MITDMA communication state. Slot Increment 1 reserves Tx 2, Slot Increment 2 reserves Tx 3, and Slot Increment 3 reserves Tx 4.

Before transmitting at Tx 2, determine the candidate slots for the next transmission, e.g. Tx 5. Randomly select a transmit slot from the canadiate slot list. This information is provided in the MITDMA communication state. Slot Increment 1 reserves Tx 3, Slot Increment 2 reserves Tx 4, and Slot Increment 3 reserves Tx 5.

If this is a broadcast message, then starting at Tx n-2, the unused Slot Inrements are set to 0. If this is an addressed message, then the following process happens.

At Tx n-2, determine the candidate slots for the acknowledgment message. Randomly select the acknowledgment slot from the candidate slot list. Calculate the offset for the ACK Slot. This information is provided in the MITDMA communication state. Slot Increment 1 reserves the Tx n-1, Slot Increment 2 reserves the Tx n, and Slot Increment 3 reserves the ACK Slot.

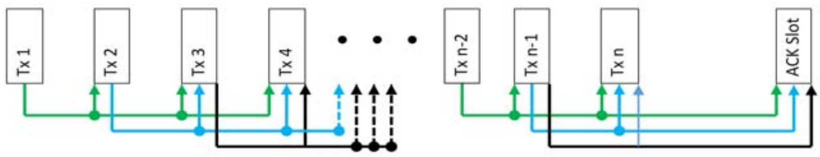
At Tx n-1 a new offset is calculated for the ACK Slot. This information is provided in the MITDMA communication state. Slot Increment 1 reserves the Tx n, Slot Increment 2 reserves the ACK Slot, and Slot Increment 3 is set to 0.

At Tx n a new offset is calculated for the ACK Slot. This information is provided in the MITDMA communication state. Slot Increment 1 reserves the ACK Slot, Slot Increment 2 and 3 are set to 0.

At the ACK Slot, the receiving station transmits the acknowledgment message.

FIGURE A2-54

[figure title?]



Commenté [JC87]: figure numbering to be revised post intersessional

6 Packet structure

The ASM transmission packets are used to transport data from one ASM station to another. There are multiple types of packet definitions which use different address modes and channel access schemes. The packet structures are defined by the message identifier.

6.1 General packet structure

The generic data packet is defined in Table A2-78.

TABLE A2-78

General packet structure

Parameter	Number of bits	Descriptions
Ramp up	8 bits	417 us
Training sequence	54 bits	Necessary for synchronization
Link configuration id	32 bits	Six information bits decoded from (32,6) biorthogonal code ASM channel configurations as defined in Link Configuration Id, see Table A1-6 Note that the Link Configuration Id will identifiy how many slots make up the message.
Message	1 slot: 352 2 slot: 864 3 slot: 1376 SAT : 1236	The symbol count and the information bits varies according to coding rate as defined by the link configuration id field
CRC	32 bits	The CRC only includes the data field
FEC termination bits	12 bits	Set to zero when not used
Ramp Down	8 bits	417 us
Guard Time	14 bits TER 154 bits SAT	Distance delay TER 729 us Distance delay SAT 8.02 ms
Total	1 slot: 512 2 slot: 1024 3 slot: 1536	

6.22 Message summary

The defined message types are summarized in the following Table A2-9table.

TABLE A2-89

Message summary

Message ID	Name	Description	Access scheme	Communication State
1	Scheduled Broadcast Message	Broadcast data using communication state	FATDMA RATDMA MITDMA	MITDMA
2	Broadcast Message	Broadcast data with no communication state	FATDMA RATDMA	none
3	Scheduled Individual Addressed Message	Individual addressed data with communication state. Requires acknowledgement	FATDMA RATDMA MITDMA	MITDMA
4	Individual Addressed Message	Individual addressed data with no communication state. Requires acknowledgement	FATDMA RATDMA	none
5	Acknowledgment Message	This message is used to provide and acknowledgment for one or more addressed messages	FATMDA RATDMA MITDMA	none
6	Geographical Multicast Message	Addressed to a group of stations defined by their geographical location with no communication state. No acknowledgment required.	FATDMA RATDMA	none
7	Group Multicast Message	Address to a group of stations defined by the group address identifier	FATDMA RATDMA	none

6.3 Message 1: Scheduled broadcast message

This ASM message is used to broadcast data to all targets, and utilizes MITDMA communication state. Multiple messages, or periodically broadcasted messages may be chained together using the MITDMA communication state. The first transmission in the chain will use RATDMA to access the link, and all additional transmission will use slots allocated by the MITDMA communication state. Scheduled broadcast message is defined in Table A2-10.

TABLE A2-910

Scheduled broadcast message

Parameter	Number of bits	Description
Message ID	4	1 - Broadcast message with MITDMA communication state
Retransmit flag	1	Indicates that this is a retransmission of data
Repeat Indicator	2	Used by the repeater to indicate how many times a message has been repeated. 0 - 3; 0 = default; 3 = do not repeat any more
Communication State	37	MITDMA communication state as described in section 3.3.3.1
Source ID	32	The Unique Identifier of the transmitting station as described in Annex 1 section 3.2
ASM identifier	16	Application identifier and described in section 5.2
Data Count	11	1 – Max data count
Binary Data	1 slot – 245 2 slot – 757 3 slot – 1269 SAT – 1129	Application data as specified by the ASM Identifier. The available length of the binary data is specified by the LinkConfigId. Unused payload data is zero-filled

6.4 Message 2: Broadcast message

This ASM message is used to broadcast data to all targets, and does not contain a communication state. These broadcast messages are used for non-periodic transmission of data, and access the link using RATDMA. Broadcast message is defined in Table A2-11.

TABLE A2-110

Broadcast Message

Parameter	Number of bits	Description
Message ID	4	2 - Broadcast message with no communication state
Retransmit flag	1	Indicates that this is a retransmission of data
Repeat Indicator	2	Used by the repeater to indicate how many times a message has been repeated. 0 - 3; 0 = default; 3 = do not repeat any more
Source ID	32	The Unique Identifier of the transmitting station as described in Annex 1 section 3.2
ASM identifier	16	Application identifier and described in section 5.2
Data Count	11	1 – Max data count
Binary Data	1 slot – 286 2 slot – 798 3 slot – 1310 SAT – 1170	Application data as specified by the ASM Identifier. The available length of the binary data is specified by the LinkConfigId.

6.5 Message 3: Scheduled addressed message

This ASM message is used to send data to an individual target, and utilizes MITDMA communication state. Multiple transmission of messages, or periodically transmissions of messages may be chained together using the MITDMA communication state. The first transmission in the chain will use RATDMA access the link, and all additional transmission will use slots allocated by the MITDMA communication state.

These transmissions require the destination station to return a message acknowledgment (Message 5). This addressed message supplies the return slot for the message acknowledgment. Scheduled addressed message is defined in Table A2-12.

TABLE A2-121

Scheduled addressed message

Parameter	Number of bits	Description
Message ID	4	3 – Individually addressed message with MITDMA communication state
Retransmit flag	1	Indicates that this is a retransmission of data
Repeat Indicator	2	Used by the repeater to indicate how many times a message has been repeated. 0 - 3; 0 = default; 3 = do not repeat any more
Communication State	37	MITDMA communication state as described in section 3.3.3.1
Source ID	32	The Unique Identifier of the transmitting station as described in Annex 1 section 3.2
Destination ID	32	The Unique Identifier of the transmitting station as described in Annex 1 section 3.2
ASM identifier	16	Application identifier and described in section 5.2
Data Count	11	1 – Max data count
Binary Data	1 slot – 213 2 slot – 725 3 slot – 1237 SAT – 1097	Application data as specified by the ASM Identifier. The available length of the binary data is specified by the LinkConfigId.

6.6 Message 4: Addressed message

This ASM message is used to send data to an individual target, and does not contain a communication state. This message is used for non-periodic transmission of data, and access the link using RATDMA.

These transmissions require the destination station to return a message acknowledgment (Message 5). The destination station will used RATDMA to send the message acknowledgment. Addressed message is defined in Table A2-13.

TABLE A2-123

Addressed message

Parameter	Number of bits	Description
Message ID	4	4 – Individually addressed message with no communication state
Retransmit flag	1	Indicates that this is a retransmission of data
Repeat Indicator	2	Used by the repeater to indicate how many times a message has been repeated. 0 - 3; 0 = default; 3 = do not repeat any more
Source ID	32	The Unique Identifier of the transmitting station as described in Annex 1 section 3.2
Destination ID	32	The Unique Identifier of the transmitting station as described in Annex 1 section 3.2
ASM identifier	16	Application identifier and described in section 5.2
Data Count	11	1 – Max data count
Binary Data	1 slot – 254 2 slot – 766 3 slot – 1278 SAT – 1138	Application data as specified by the ASM Identifier. The available length of the binary data is specified by the LinkConfigId.

6.67 Message 5: Acknowledgment message

This ASM message is used to return message acknowledgments to one or more addressed messages. Note that this message should always use Link Configuration Id of 8 (1/2 coding rate). Acknowledgement message is defined in Table A2-14.

TABLE A2-143

Acknowledgment message

Parameter	Number of bits	Description
Message ID	4	5 – Multiple acknowledgment message with no communication state
Retransmit flag	1	Indicates that this is a retransmission of data
Repeat Indicator	2	Used by the repeater to indicate how many times a message has been repeated. 0 - 3; 0 = default; 3 = do not repeat any more
Source ID	32	The Unique Identifier of the transmitting station as described in Annex 1 section 3.2
Destination ID	32	The Unique Identifier of the transmitting station as described in Annex 1 section 3.2
ACK/NACK Mask	16	Specifies which MITDMA block ids failed. Bit map field with the LSB representing Block id 1, the MSB representing Block Id 16. "1" indicates a packet failed "0" indicates the packet was received ok
Coding rate adaption request	2	0: Maintain MCS 1: Increment MCS (higher rate) 2: Decrease MCS 3: Reserved for future uses
Signal Quality Indicator	8	Received C/N0 in dBHz
Zero padding	As required	Padding bits are added as require to complete the block size.

6.68 Message 6: Geographical multicast message

This ASM message is used to broadcast data to a group of stations as defined by the specified geographical area. The broadcast message does not contain a communication state. These broadcast messages are used for non-periodic transmission of data, and access the link using RATDMA. Geographical multicast message is defined in Table A2-15.

TABLE A2-154

Geographical multicast message

Parameter	Number of bits	Description
Message ID	4	6 – Geographical addressed message with no communication state
Retransmit flag	1	Indicates that this is a retransmission of data
Repeat Indicator	2	Used by the repeater to indicate how many times a message has been repeated. 0 - 3; 0 = default; 3 = do not repeat any more
Source ID	32	The Unique Identifier of the transmitting station as described in Annex 1 section 3.2
Longitude 1	18	Longitude of area to which the group assignment applies; upper right corner (north-east); in 1/10 min (±180°, East = positive, West = negative)
Latitude 1	17	Latitude of area to which the group assignment applies; upper right corner (north-east); in 1/10 min (±90°, North = positive, South = negative)
Longitude 2	18	Longitude of area to which the group assignment applies; lower left corner (south-west); in 1/10 min (±180°, East = positive, West = negative)
Latitude 2	17	Latitude of area to which the group assignment applies; lower left corner (south-west); in 1/10 min (±90°, North = positive, South = negative)
ASM identifier	16	Application identifier and described in section 5.2
Data Count	11	1 – Max data count
Binary Data	1 slot – 216 2 slot – 728 3 slot – 1240 SAT – 1100	Application data as specified by the ASM Identifier. The available length of the binary data is specified by the LinkConfigId.

6 Satellite uplink message

Satellite uplink may be provided by VDES equipment. It also may provide by dedicated equipment using slot carrier sense TDMA (SCTDMA) access scheme to consolidate AIS communications and terrestrial ASM communications.

6.1 Packet bit structure for satellite uplink message

The data packet for ITDMA, RATDMA and FATDMA is defined in Table A2-8.

The data packet for SCTDMA is as defined in Table A2-9.

TABLE A2-8

Modified packet bit structure for satellite uplink

Slot composition	Bits	Notes
Ramp up	816	Standard
Pre training sequence	100	0011 (repeat for 100 bits)
Training sequence	5427	Standard
Link Configuration IdSignal information	327	Decoded from [Hamming (16,6)] ASM channel configurations as defined in Link Configuration Id tableDecoded from Hamming (7,4) 0000 – not codingMCS-0 0001 – 1/2 code rateMCS-1 0010 – 3/4 code rate… 110011 – 5/6 code rateMCS-15, see Table A1-5.1[TBD]
Data length	10	Default: "0011000110" (198) encoded data and CRC;
Data field	2321 66	Without encoding: 232166 bits With encoding: varies according to coding rate defined in the Signal Information field
CRC	32	Without encoding: 32 bits; With encoding: varies according to coding rate defined in the Signal Information field; Only the data length and data field isare included in the CRC
Guard TimeBuffer	154	Synch jitter (mobile station) = 6 bits Synch jitter (mobile/satellite) = 2 bits Propagation time delay difference = 144 bits Spare = 2 bits
Total	512	Maximum 512 bits for 19.2 kbits/s π/4 QPSK

TABLE A2-9

Modified packet bit structure for satellite uplink ASM message with SCTDMA

Slot composition	Bits	Notes
Carrier sense period	56	Not transmitting (2 917 µs, equivalent to 56 bits)
Ramp up	816	Standard
Pre training sequence	44	0011 (repeat for 44 bits)
Training sequence	5427	Standard
Link Configuration IdSignal information	327	Decoded from [Hamming (16,6)] ASM channel configurations as defined in Link Configuration Id tableDecoded from Hamming (7,4) 0000 – MCS-0 0001 – MCS-1 ... 1111 – MCS-15, see Table A1-5.1[TBD]0000 – not coding 0001 – 1/2 coding 0010 – 3/4 coding 0011 – 5/6 coding
Data length	10	Default: "0011000110" (198) encoded data and CRC;
Data field	1766	Without encoding:1766 bits With encoding: varies according to coding rate defined in the Signal Information field
CRC	32	Without encoding: 32 bits; With encoding: varies according to coding rate defined in the Signal Information field; Only the data length and data field are included in the CRC
Guard Time	154	Synch jitter (mobile station) = 6 bits Synch jitter (mobile/satellite) = 2 bits Propagation time delay difference = 144 bits Spare = 2 bits
Total	512	512 bits for 19.2 kbits/s π/4 QPSK

6.69 Message 7: Group multicast message

This ASM message is used to broadcast data to a group of stations as defined by the specified geographical area. The broadcast message does not contain a communication state. These broadcast messages are used for non-periodic transmission of data, and access the link using RATDMA. Group multicast message is defined in Table A2-16.

TABLE A2-164

Group multicast message

Parameter	Number of bits	Description
Message ID	4	7 – Group addressed message with no communication state
Retransmit flag	1	Indicates that this is a retransmission of data
Repeat Indicator	2	Used by the repeater to indicate how many times a message has been repeated. 0 - 3; 0 = default; 3 = do not repeat any more
Source ID	32	The Unique Identifier of the transmitting station as described in Annex 1 section 3.2
Group Destination ID	32	The Unique Identifier of a group of receiving
ASM identifier	16	Application identifier and described in section 5.2
Data Count	11	1 – Max data count
Binary Data	1 slot – 254 2 slot – 766 3 slot – 1278 SAT – 1138	Application data as specified by the ASM Identifier. The available length of the binary data is specified by the LinkConfigId.

TABLE A2-9 (*end*)

Slot composition	Bits	Notes
CRC	32	Without encoding: 32 bits; With encoding: varies according to coding rate defined in the Signal Information field; Only the data length and data field are included in the CRC
Long-range ASM receiving system buffer	154	Synch jitter (mobile station) = 6 bits Synch jitter (mobile/satellite) = 2 bits Propagation time delay difference = 144 bits Spare = 2 bits
Total	512	Maximum 512 bits for 19.2 kbits/s π/4 QPSK

6.2 Transmitting the satellite uplink broadcast message

The satellite uplink ASM broadcast message should be transmitted only on ASM channels and not on the following channels: 75, 76, AIS 1, AIS 2 or regional channels.

Annex 3

Technical characteristics of VDE-terrestrial in the maritime mobile band

1 Introduction

This section describes those elements of the VDE-TER that are unique to VDE-TER operation. For those elements that are common, the cross reference into Annex 1 is provided. This annex describes the characteristics of the terrestrial VDES. It contains a description of the different protocols according to the OSI layer model and recommends implementation details for each layer.

Commenté [SP88]: Work item 98

Data transmission is made in the VHF maritime mobile band. Data transmissions are made within the spectrum allocated for the VDE1-A and VDE1- B. The spectrum may be used as 25 kHz, 50 kHz or 100 kHz channels.

The system should use TDMA techniques in a synchronized manner.

2 OSI layer

Refer to Annex 1 § 3.2.

3 Physical layer

3.1 Range

The communication range of terrestrial VDE is typically 20−50 NM.

3.2 Transmitter Parameter settings

Refer to Annex 1 for transmitter parameter settings for mobile stations.

Transmitter parameter settings for shore station are defined in Table A3-1.

TABLE A3-1

Transmitter parameters shore station

Transmitter parameters	Requirements	Condition
Frequency error	3 ppm	normal
Transmit power	Transmit average power shall be at least 12.5 watts and not exceed 50 watts as declared by the manufacturer. ±1.5 dB normal +2/–6 dB extreme	conducted
Modulation spectrum 25 kHz channel	0 dBc –25 dBc –60 dBc	Δfc < ±12.5 kHz ±12.5 kHz < Δfc < ±25 kHz ±25 kHz < Δfc < ±75 kHz
Modulation spectrum 50 kHz channel	0 dBc –25dBc –60 dBc	Δfc < ±25 kHz ±25 kHz < Δfc < ±50 kHz ±50 kHz< Δfc < ±100 kHz
Modulation spectrum 100 kHz channel	0 dBc –25 dBc –60 dBc	Δfc < ±50 kHz ±50 kHz < Δfc < ±100 kHz ±100 kHz < Δfc < ±150 kHz
Spurious emissions	–36 dBm –30 dBm	9 kHz ... 1 GHz 1 GHz ... 4 GHz

Commenté [SP89]: Same rationale as for table A2-2

3.3 Antenna

Terrestrial VDE may share the same antenna(s) with the other subsystems AIS, ASM, VDE-SAT.

Refer to Annex 1.

3.4 Modulation

3.4.1 Waveforms

The waveforms are defined in Annex 1, Modulation and Coding SchemesTABLE Table A1-96A3-2.

The modulation and coding options and raw channel throughput rates are provided for a range of bandwidths and modulation and coding schemes (MCS). Three MCSs are detailed while 13 others are reserved for future expansion.

TABLE A3-2

Modulation and coding schemes

Modulation and coding scheme	Signal Information D_0, D_1, D_2, D_3 values	CQI value	Total throughput bitrate (kbits/s)* 25 kHz	Total throughput bitrate (kbits/s)** 50 kHz	Total throughput bitrate (kbits/s)*** 100 kHz
No transmission		0	–	–	–
MCS-1 (π/4 QPSK, CR = 1/2)	0, 0, 0, 1	1	38.4	76.8	153.6
MCS-2	0, 0, 1, 0	2	Placeholder for future MCS		
MCS-3 (8PSK, CR = 3/4)	0, 0, 1, 1	3	57.6	115.2	230.4
MCS-4	0, 1, 0, 0	4	Placeholder for future MCS		

Modulation and coding scheme	Signal Information D_0, D_1, D_2, D_3 values	CQI value	Total throughput bitrate (kbits/s)* 25 kHz	Total throughput bitrate (kbits/s)** 50 kHz	Total throughput bitrate (kbits/s)*** 100 kHz
MCS-5 (16QAM, CR = 3/4)	0, 1, 0, 1	5	76.8	153.6	307.2
Placeholder for future MCS	X, X, X, X	Placeholder for future MCS			
* An assumption: 19.2 ksym/s in 25 kHz bandwidth (Roll-off factor: 0.3) ** An assumption: 38.4 ksym/s in 50 kHz bandwidth (Roll-off factor: 0.3) *** An assumption: 76.8 ksym/s in 100 kHz bandwidth (Roll-off factor: 0.3)					

3.44.212 Bit Mapping

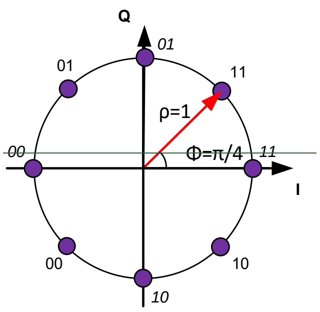
For bit mappings, see Annex 1, § section 3.98.

Commenté [SP90]: Moved bit mappings to Annex 1 according to work item 10

The bit mapping is shown in figures Figs. A3-1, A3-2 and A3-3.

FIGURE A3-1

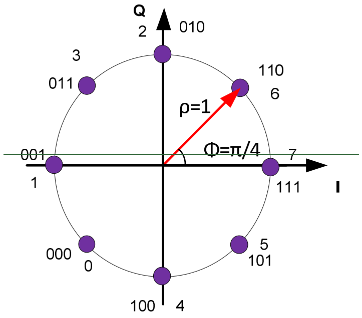
Bit Mapping for π/4 QPSK



NOTE – Each subsequent transmission is phase-rotated by $\pi/4$.

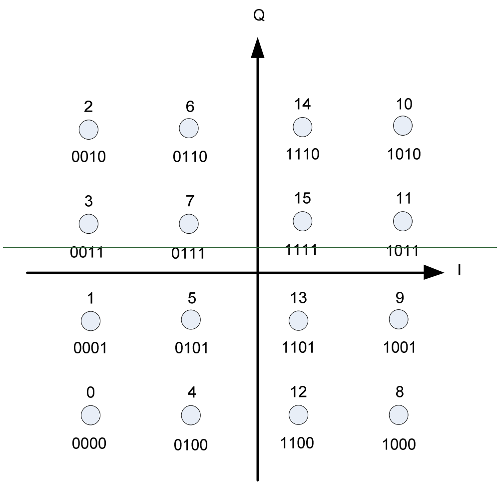
~~FIGURE A3-2~~

~~Bit Mapping for 8PSK~~



~~FIGURE A3-3~~

~~Bit Mapping for 16QAM~~



3.5 Sensitivity and Interference

VDE uses adaptive modulation and coding to maximise spectral efficiency and throughput. Sensitivity and interference levels for the supported modulation methods are given in Table A3-~~3~~1.

TABLE A3-31

Sensitivity and Carrier to Interference Ratios

Modulation Coding Scheme	25 kHz		50 kHz		100 kHz	
	Sensitivity (dBm)	CIR (dB)	Sensitivity (dBm)	CIR (dB)	Sensitivity (dBm)	CIR (dB)
MCS-1*	−110	8	−107	8	−104	8
MCS-3*	−104	14	−101	14	−98	14
MCS-5*	−102	16	−99	16	−96	16

* Modulation Coding Schemes, see Table AA1-63-2. This table assumes a BER of 1e-6.

Commenté [JC91]: Confirm ref

TBD: add missing receiver parameters (look at Table A2-1).

3.6 Symbol timing accuracy

Symbol timing accuracy is less than 5 parts per million (ppm).See Annex 1, § 3.2.4.1.1.

3.7 Transmitter timing jitter

Less than 5% symbol interval (peak).See Annex 1, § 3.2.4.1.2.

3.8 Slot transmission accuracy at the output

Less than 100 µs peak relative to UTC reference time for the ship station.

Less than 50 µs peak relative to UTC reference time for the shore station.See Annex 11, § 3.2.4.1.3.

3.9 FrameSlot structure

For the generic definition of the frame structure, sSee Annex 1, § 3.3.

The VDES frame structure is identical and synchronized in time to UTC (as in AIS). The slot structure is shown in Fig. A3-4. Each element is described in the subsequent sections. Table A3-4 shows the resulting net bitrates (Data bits of the slot structure).

FIGURE A3-4

Slot structure

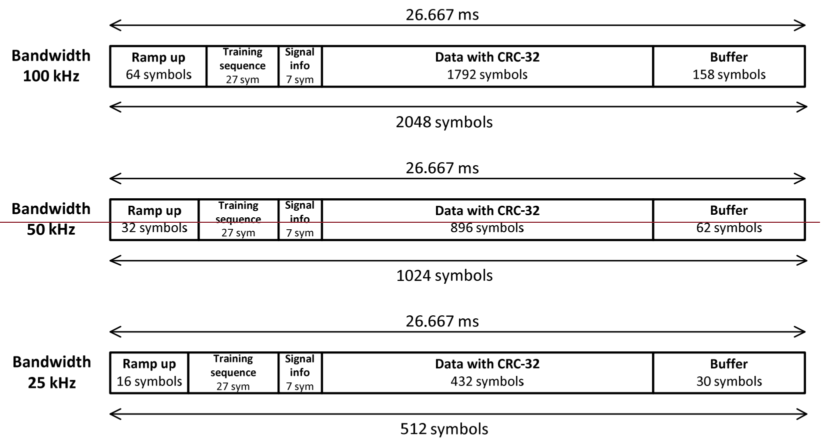


TABLE A3-4

Resulting net bitrates (Data)

NET user data bitrate per channel [kbps][6]			
	Bandwidth		
	25 kHz	50 kHz	100 kHz
MCS-1	15	32	66
MCS-3	35	74	150
MCS-5	47	100	200

3.9.1 Ramp up

The ramp up time from −50 dBc to −1.5 dBc of the power shall occur in less than or equal to 832 µs. This is a means to maintain compliancy with the adjacent channel interference requirements.

3.9.2 Training sequence

The training sequence is 111111001101010000011001010.

3.9.3 Signal information

The signal information carries the MCS id for the receiver.

[6] Amount of aggregate user data which can be carried by the MSC scheme on a single channel assuming single slot packets including coding and other message encapsultion according to the MSC definition.

~~The signal information should follow the training sequence for transmissions, see Table A3-2.~~

~~The signal information consists of 4 bits (D0, D1, D2, D3) encoded into a sequence of 7 bits using Hamming (7,4) code.~~

~~3.9.4 Bit mapping for training sequence and signal information~~

~~For training and signal information, following mapping applies:~~

~~– 1 maps to QPSK symbol 3 (1, 1) (see Fig. A3-1)~~

~~– 0 maps to QPSK symbol 0 (0, 0).~~

~~For QPSK bit mapping, see § 3.4.2.~~

~~3.9.5 Data with CRC-32~~

~~The data payload with its appended CRC-32 is interleaved (refer to Table A1-2), encoded (refer to Annex 1, chapter 3.5.1) and then scrambled (refer to Annex 1, chapter 3.[TBD]) and bit mapped.~~

~~Unused payload data is zero-filled.~~

~~3.9.6 Forward error correction~~

~~Refer to Annex 1.~~

~~3.9.7 Bit scrambling~~

~~Scrambling of the user data is required to avoid the power spectral density to be concentrated in the narrow band. See Annex 1 for the detailed definition of the scrambler sequence.~~

~~3.9.8 Buffer~~

~~The buffer consists of the ramp down time from full power to −50 dBc of less than or equal to 832 µs. The remaining time is for delay and jitter.~~

4 Link layer

4.1 Access Schemes

The VDE terrestrial system should support the following TDMA access schemes:

– FATDMA;

– –?? ~~RATDMA~~;

– ~~ITDMA~~ATDMA.

4.2 Data encapsulation

~~The data field consists of multiple variable length datagrams and these are encapsulated. Each datagram contains the following encapsulation fields:~~

~~– Datagram type;~~

~~– Datagram size;~~

~~– Destination (optional);~~

~~– Transaction ID (optional);~~

~~– Datagram sequence number (for multi-segment datagrams);~~

~~– Source ID;~~

~~– Datagram payload (variable);~~

– Data padding;
– CRC (4 bytes).Refer to Annex 1.

4.3 Cyclic redundancy check

Refer to Annex 1.

4.4 Automatic repeat request (ARQ)

Datagrams may or may not use ARQ, this is defined for each datagram type. An ARQ may request selective retransmission of a specific lost datagram segment.Refer to Annex 1.

4.5 Acknowledgement (ACK)

Unicast datagrams without CRC errors that are acknowledged over the VDE link should be sent with a receive signal channel quality indicator (CQI).Refer to Annex 1.

4.6 End delivery notification (EDN)

All datagrams requiring delivery notifications that are successfully delivered to the destination should be notified to the source. Refer to Annex 1.

4.7 End delivery failure (EDF)

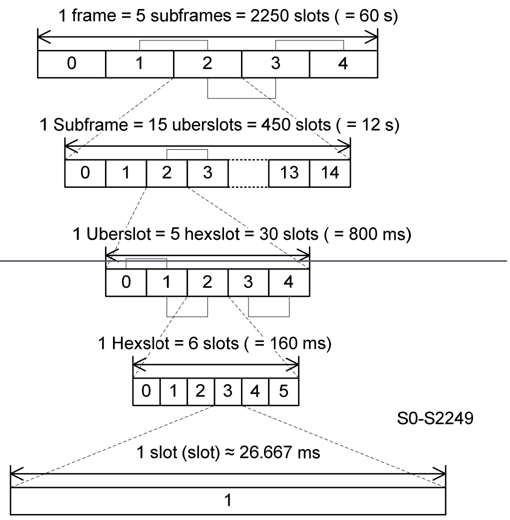
All datagrams requiring delivery notifications that are not successfully delivered within the timeout or retry limit should be notified to the source. Refer to Annex 1.

4.8 Frame hierarchy

Refer to Annex 16.

FIGURE A3-15

Frame hierarchy



4.9 Channel resource and media access control for VDE terrestrial

VDE spectrum (and logical channel) resources are allocated by the reception of shore (or satellite-based) media access control messaging (for example, shore stations perform this operation using the bulletin board service). In the event of vessel reception of, both satellite and shore-based stations, the shore-based resource allocations should take precedence.

Duplexing modes are a function of the resource allocation above, as well as the operational mode.

4.9.1 Simplex modes

– Ship-to-ship

Same channel resource is used for both directions of communications.

4.9.2 Duplex modes

– Shore-to-ship

– Ship-to-shore

Upper and lower spectrum are used for ship to shore or shore to ship respectively, only one side transmits at one time.

Refer to Annex 1 for details of frequency allocations.

4.10 Physical and logical channels

VDES uses several channels to carry data. These channels are separated into Physical and Logical channels. A bulletin board may prescribe this channel usage.~~Shore-based stations should transmit a channel terrestrial bulletin board (TBB) message that defines the configuration of the VDE channels.~~

Lacking bulletin board information, ship borne stations should employ a default channel configuration of 10~~5~~0 kHz channels on the terrestrial VDES (channel 2024~~, and,~~ 2084, 2025 and 2085 combined) operating in a simplex ad-hoc access scheme. The simplex ad-hoc access scheme for ship-to-ship communications should be ~~ITDMA~~ATDMA ~~(when possible) or RATDMA.~~

4.11 Physical channels

The physical channels (PC) are determined by the centre frequency and bandwidth.

4.12 Logical channels

The logical channels (LC) are divided into signalling and traffic channels. These are described below. Logical channel definitions can be defined based on the physical channel and message time information (frame hierarchy, start time, etc.).

Signalling channels:

– Terrestrial Bulletin Board (TBB), see § 4.12.1

– Announcement, see § 4.12.2

– Random access, see § 4.12.5.

All signalling channels use the most robust modulation and coding scheme.

Traffic channels:

– Multicast, see § 4.12.3

– Unicast, see § 4.12.4

– Random access, see § 4.12.5.

Commenté [JC92]: Should this be a numbered heading?

Commenté [JC93]: Should this be a numbered heading?

Traffic channels may use a combination of robust and higher bitrate modulation and coding schemes.

4.12.1 Terrestrial bulletin board (TBB) signalling channel

Each VDE shore station should employ a fixed logical channel for the TBB. All TBB logical channels will be based on one of a number of predefined structures of the frame hierarchy 50 kHz shore to ship physical channel (2024 and 2084 combined). These are defined to occupy only a portion of the frame (60 seconds, 2 250 slots) to permit possible spectrum and temporal sharing with satellites, see Annex 6.

The TBB defines the network configuration parameters such as signalling channels (control channels) and data channel(s), protocol versions and future network configuration. The TBB takes precedence in the allocation of spectrum (logical channel) resources. This may be co-ordinated with the satellite bulletin board signalling channel to facilitate sharing of mutual spectrum resources.

The logical channels are normally repeated based on the VDES frame hierarchy.

The VDE terrestrial channel usage for the service area of VDE shore station is defined by the TBB, see Annex 1.

The TBB information includes the area of applicability. The TBB does not change often and should be transmitted in regular intervals.

4.12.2 Announcement signalling channel (ASC)

This channel(s) will normally carry announcements, MAC information, VDE forward and return resource allocation, CQIs, ARQs, and ACKs. Announcements also include the co-ordination of uni-cast and multi-cast (broadcast) datagrams.

The MAC information includes changes to network version, congestion control (randomization interval (hold-off) and minimum priority level). Some of these parameters will be reflected in the TBB on periodic basis.

The ASC logical channels will be assigned in the TBB and consist of a number of defined structures of the frame hierarchy 50 kHz shore to ship physical channel (2024 and 2084 combined). These are defined to occupy only a portion of the frame (60 seconds, 2 250 slots) to permit possible spectrum and temporal sharing with satellites, see Annex 6.

The ASC defines the physical channel usage (logical channel, i.e. frequency and slot) to an individual ship following a resource request. The VDE shore station uses CQI information from the ship terminal to select the highest throughput format with adequate link margin.

4.12.3 Multicast data channel (MDC)

This traffic channel(s) is utilized to send messages to be received by a large number of ships. By default multicast messages are addressed to all stations (i.e. broadcast).

4.12.4 Unicast data channel (UDC)

This traffic channel is allocated a specific ship for the duration of a unicast datagram.

This channel is set up after a ship responds to an announcement, and the response includes received channel quality information (CQI) allowing the shore station to maximise throughput.

4.12.5 Random access channel (RAC)

This channel has the characteristics of a slotted Aloha channel, uses a random access scheme and will be selected from a predefined list of logical channels.

4.12.5.1 For ship-to-shore, and shore-to-ship communications

A ship station uses this channel to access the network or send a short message.

4.12.5.2 For ship-to-ship when ships are within control area of a VDE shore station

A ship station uses this channel to communicate directly with other ships. This logical channel is allocated by shore station via TBB or ASC.

4.12.5.3 For ship-to-ship when outside the control area of a shore VDE station

A ship station uses these channels to communicate with other ship stations directly via short message, and will also use these random access channels to co-ordinate communication with other ships for larger messages. These logical channels will be based on a number of predefined structures of the frame hierarchy of the ship-to-ship physical channels (2024, and 2084, 2025 and 2085 combined). Ship-to-ship random access channels should have fixed physical channel assignments and use the most robust modulation and coding scheme. These logic channels are distinct from the TBB logical channels.

5 Network layer

Refer to Annex 1, whereassuming the "Control Station" refers to in the terrestrial context can be anya shore station in receiving range.

5.1 Terrestrial data transfer protocols

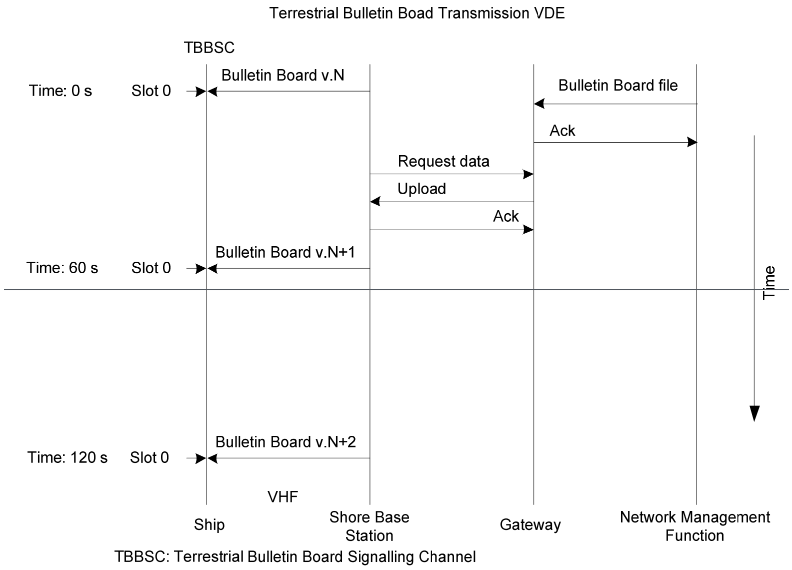
The following types of transmissions should be supported:

– Bulletin Board transmission from shore station (network configuration)
– Multicast from shore station (e.g. icemaps, weather info, notices to mariners)
– Unicast from shore station (e.g. shore-to-ship file transfer)
– Multicast from ship-to-ship (e.g. icemaps, weather info, notices to mariners)
– Unicast from ship-to-shore (e.g. ship-to-shore file transfer)
– Unicast from ship-to-ship (e.g. ship-to-ship file transfer)
– Shore originated polling (e.g. shore-to-ship-to-shore).

Figures A3-6 2 to A3-9 4 show message sequence charts for the shore originated cases. In order to manage logical channel congestion on the ASC, as shown in message sequence charts, functions such as ARQ or ACK may be inhibited at source through setting of a status bit. This may be beneficial in the case of multicast (or broadcast) messages transmitted to a large population of vessels, some of which may be beyond the nominal coverage area of the shore-originated multicast as shown in Fig. A3-73.

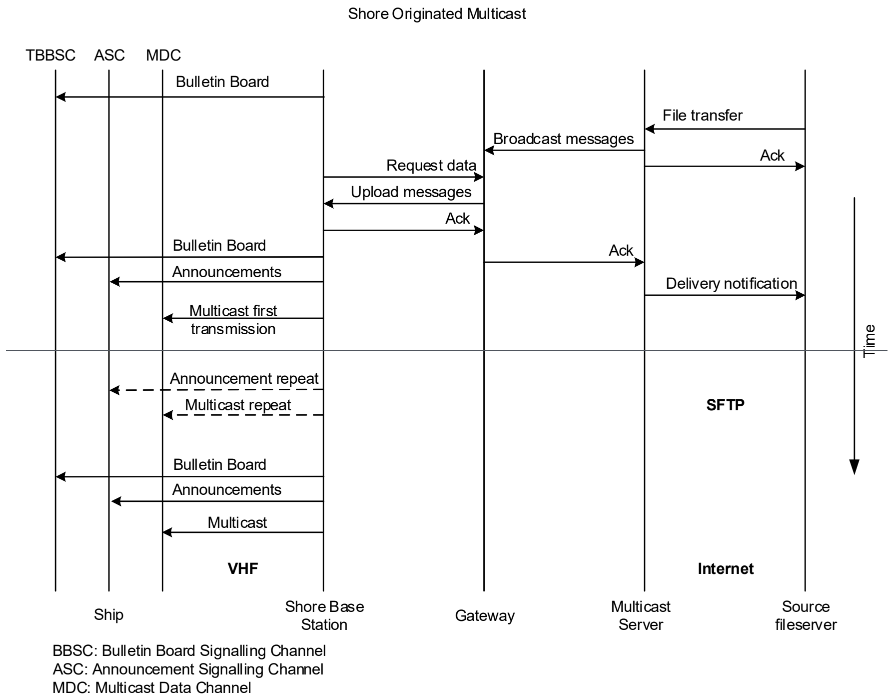
~~Figure A3-26~~

~~Terrestrial bulletin board with network version change~~



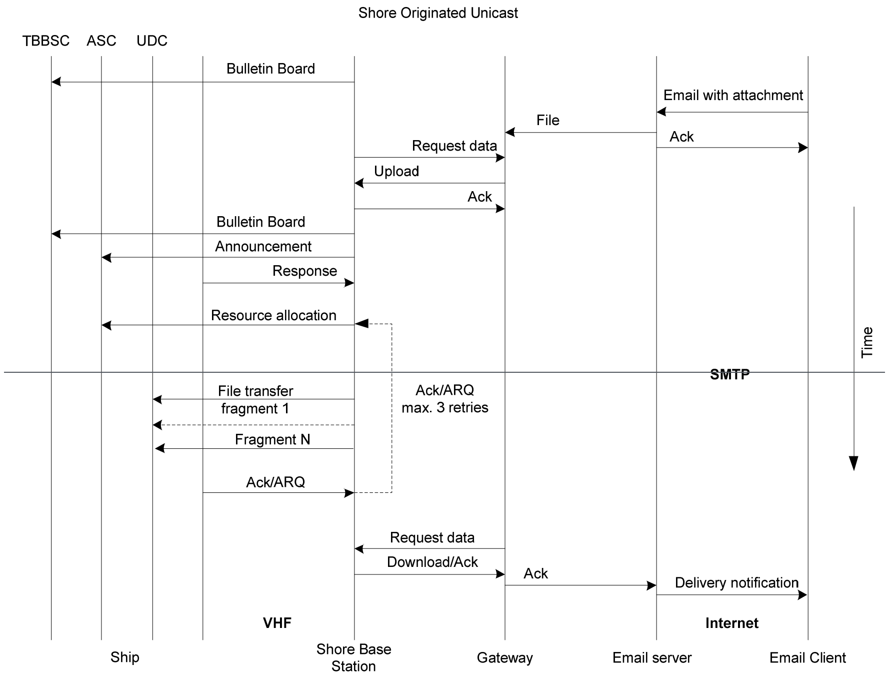
~~Figure A3-37~~

~~Shore originated multicast~~



~~Figure A3-48~~

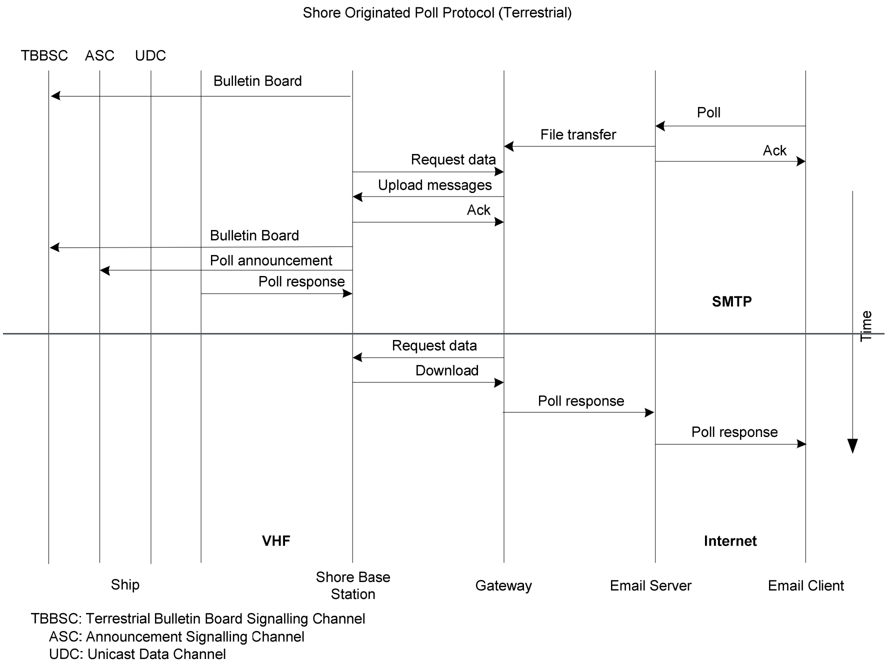
~~Shore originated unicast (file transfer) protocol~~



TBBSC: Terrestrial Bulletin Board SignallingCchannel
ASC: Announcement Signalling Channel
UDC: Unicast Data Channel

Figure A3-59

Shore originated poll protocol



6 Transport layer

Existing Internet protocols including TCP, UDP, SNMP, Secure File Transfer Protocol (SFTP), Simple Mail Transfer Protocol (SMTP) as shown in Figs. A3-6 3 to A3-9 5 should be supported.

Terrestrial IP protocols are terminated at the terrestrial network gateway.Refer to Annex 1.

Annex [VDESAT]4

Technical characteristics of VDE-SAT service in the VHF maritime mobile band

1 Introduction

This section describes those elements of the VDE-SAT that are unique to VDE-SAT operation. For those elements that are common, the cross reference into Annex 1 is provided.This annex describes the characteristics of the VDE-SAT uplink and downlink services of the VHF Data Exchange System (VDES). In this context, the following types of functionality are envisaged:

– VDE-SAT allows two-way communications and transmit-only:

– Shore initiated polling of information from ships (satellite-ship-satellite)

– Ship initiated enquiry for information from shore (ship-satellite-ship)
– Ship initiated data transfer to shore (ship-satellite)
– Collection of information from transmit-only VDES terminals (ship-satellite). This could be either event driven or periodic. The time-slotslot and frequency band for this service should be assigned by the bulletin board and announcement signalling channels.
– Downlink multicast multi-packet data transfer (satellite-ship)
– Shore originated unicast multi-packet data transfer via satellite (satellite ship)

In this annex low earth orbit (LEO) satellites with 600 km altitude are considered to present typical examples of VDE satellite solutions. It should be noted that other orbital selections are also possible according to the overall system design consideration.

The focus of this annex is to describe the physical layer of the OSI model as defined in Annex 1. The overall description of the link, network and the transport layers is provided in Annex 1.

2 VDE-SAT physical layer

2.1 VDE-SAT uplink key parameters

This section outlines assumptions regarding the VDE-SAT system parameters that are used as representative examples in this annex.

2.1.1 Satellite to surface distance range

The orbit height determines the satellite range variations. For example, for a 600 km LEO the maximum range is 2 830 km. For timing purposes a maximum range of 3 000 km will be used.

The minimum range is equal to the orbit height. For a LEO satellite at 600 km altitude the minimum range will be 600 km. This value is used to determine the minimum propagation delay time. Considering these exemplary values for the minimum and maximum ranges, the path delay will vary from 2 ms to 10 ms, a variation of 8 ms as shown in Figure A[VDESAT]4-1 and Figure A[VDESAT]4-2.

For the VDE-SAT downlink, in addition to the relative delays between signal receptions at a vessel from different satellites, there could be absolute delay due to other sources such as signal processing delay. The satellite service provider should pre-compensate for absolute delay.

FIGURE A[VDESAT]4-1

VDE-SAT downlink timing

VDE-SAT downlink timing

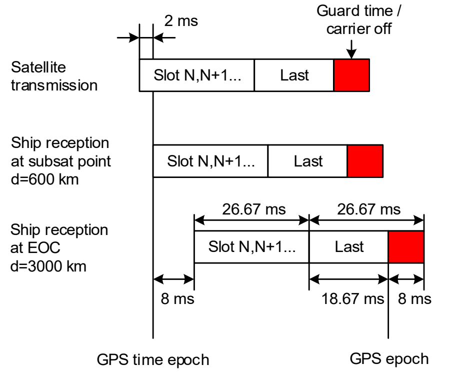
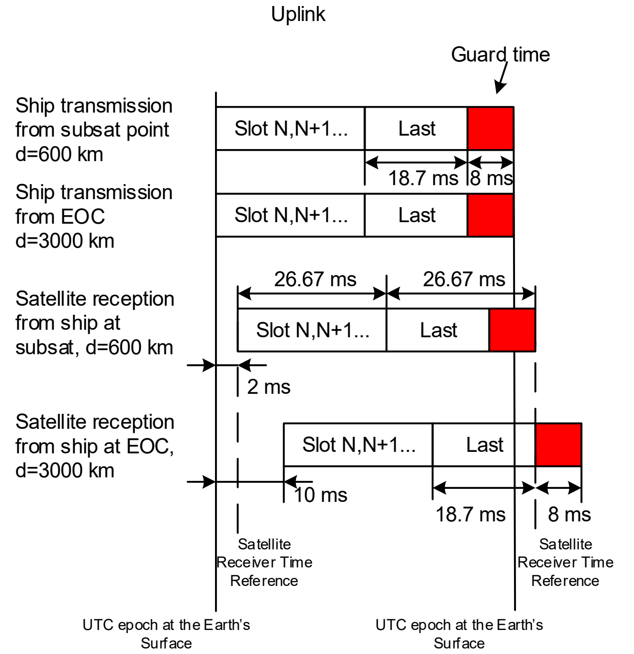


FIGURE A[VDESAT]4-2

VDE-SAT Uplink timing

VDE-SAT Uplink timing



2.1.2 Satellite transmission carrier frequency error

The satellite transmission carrier frequency error is the sum of the satellite transmission frequency error and Doppler, and the frequency uncertainty at the receiver. The transmit frequency error at the satellite shall be less than 1 ppm, i.e. ±160 Hz.

A LEO satellite will move at a speed of about 8 km/s and this will cause a maximum Doppler of ±4 kHz at VHF.

2.1.3 Ship station transmitter requirements

For ship station transmitter requirements, see Annex 1.

2.1.4 Ship station antenna gain

For ship station antenna gain, see Annex 1.

2.1.5 Ship station noise plus interference level

For noise plus interference level of ship station, see Annex 1.

2.2 Link budget analysis

The link C/N_0 is determined by the transmitted e.i.r.p., path losses, propagation losses, receiver sensitivity/figure of merit and local interference levels.

2.2.1 VDE-SAT downlink link budget

Examples of link budgets for the VDE-SAT downlink are provided in the following sections.

2.2.1.1 Satellite downlink e.i.r.p.

The e.i.r.p. can be derived from PFD mask given in Table A[VDESAT]4-1.

TABLE A[VDESAT]4-1

Proposed power spectral and PFD mask

$$\theta^\circ = \boldsymbol{earth - satellite\ elevation\ angle}$$

$$PFD(\theta^\circ)_{\ (\mathrm{dBW/(m^2*4\ kHz)})} = \begin{cases} -149 + 0.16 * \theta^\circ & 0^\circ \le \theta < 45^\circ; \\ -142 + 0.53 * (\theta^\circ - 45^\circ) & 45^\circ \le \theta < 60^\circ; \\ -134 + 0.1 * (\theta^\circ - 60^\circ) & 60^\circ \le \theta \le 90^\circ. \end{cases}$$

Table A[VDESAT]4-2 shows the theoretical maximum satellite e.i.r.p. as a function of elevation angles for this mask.

TABLE A[VDESAT]4-2

Satellite maximum e.i.r.p. vs. elevation angle

Ship Elevation angle θ	Powerflux density on ground	Satellite range	Maximum downlink satellite e.i.r.p.
(degrees)	(dBW/m²/4 kHz)	(km)	(dBW in 25 kHz)
0	−149.0	2 831	−1.0
10	−147.4	1 932	−2.7
20	−145.8	1 392	−4.0
30	−144.2	1 075	−4.6
40	−142.6	882	−4.7
50	−139.4	761	−2.8
60	−134.0	683	1.6
70	−133.0	635	2.0
80	−132.0	608	2.6
90	−131.0	600	3.5

2.2.1.2 Satellite e.i.r.p. vs. elevation

Most of the satellite coverage area and visibility time will be at low elevation angles, and high elevation angle coverage may be sacrificed without significant system capacity loss.

The following two satellite antennas have been analysed and are acceptable.

1) Yagi Antenna: For this antenna the link budget is optimised for 0 degrees ship elevation angle using a three element Yagi antenna with the satellite pointed at the horizon is given in Table A[VDESAT]4-3. Assuming a peak antenna gain of 8 dBi, a transmit RF power of −12.4 dBW in 25 kHz will ensure compliance with the PFD limit. Satellite e.i.r.p. vs. ship elevation is shown in Table A[VDESAT]4-3.

TABLE A~~[VDESAT]~~4-3

Satellite e.i.r.p. vs. elevation using a Yagi antenna

Ship elevation angle	Nadir offset angle	Boresight offset	Satellite antenna gain	Satellite e.i.r.p. in circular polarization	Satellite range	PFD	Table A4-1 PFD limit	PFD margin
degrees	degrees	degrees	dBi	dBW	km	dBW/m²/4 kHz	dBW/m²/ 4 kHz	dB
0	66.1	0	8	−4.4	2 830	−152.4	−149.0	3.4
10	64.2	1.9	8	−4.4	1 932	−149.1	−147.4	1.7
20	59.2	6.9	8	−4.4	1 392	−146.2	−145.8	0.4
30	52.3	13.8	7.8	−4.6	1 075	−144.2	−144.2	0.0
40	44.4	21.7	6.9	−5.5	882	−143.4	−142.6	0.8
50	36	30.1	5.5	−6.9	761	−143.5	−139.4	4.1
60	27.2	38.9	3.6	−8.8	683	−144.5	−134.0	10.5
70	18.2	47.9	0.7	−11.7	635	−146.7	−133.0	13.7
80	9.1	57	−2.2	−14.6	608	−149.2	−132.0	17.2
90	0	66.1	−5.5	−17.9	600	−152.4	−131.0	21.4

2) Isoflux antenna: This antenna is designed to point at the nadir direction providing a symmetric radiation pattern around the pointing direction. Assuming a peak antenna gain of 2 dBi, a transmit RF power of −5 dBW in 25 kHz will ensure compliance with the PFD limit. Satellite e.i.r.p. vs. ship elevation is shown in Table A~~[VDESAT]~~4-4.

TABLE A~~[VDESAT]~~4-4

Satellite e.i.r.p vs. elevation using an isoflux antenna

Ship elevation angle	Nadir offset angle	Boresight offset	Satellite antenna gain	Satellite e.i.r.p. in circular polarization	Satellite range	PFD	Table A4-1 PFD limit	PFD margin
degrees	degrees	degrees	dBi	dBW	km	dBW/m²/4 kHz	dBW/m²/4 kHz	dB
0	66.1	0	2	−3.0	2 830	−151.0	−149.0	2.0
10	64.2	1.9	1.5	−3.5	1 932	−148.2	−147.4	0.8
20	59.2	6.9	1	−4.0	1 392	−145.8	−145.8	0.0
30	52.3	13.8	−0.5	−5.5	1 075	−145.1	−144.2	0.9
40	44.4	21.7	−2	−7.0	882	−144.9	−142.6	2.3
50	36	30.1	−4	−9.0	761	−145.6	−139.4	6.2
60	27.2	38.9	−5	−10.0	683	−145.7	−134.0	11.7
70	18.2	47.9	−7	−12.0	635	−147.0	−133.0	14.0
80	9.1	57	−8	−13.0	608	−147.6	−132.0	15.6
90	0	66.1	−8.5	−13.5	600	−148.0	−131.0	17.0

2.2.1.3 Link $C/(N_0+I_0)$

The nominal signal level and $C/(N_0+I_0)$ vs. elevation for a 25 kHz channel are provided in Table A~~[VDESAT]~~4-3 and Table A~~[VDESAT]~~4-4 for Yagi and Isoflux on-board antennas. The assumed ship antenna gain is 3 dBi and the system noise temperature is 30.2 dBK as shown in Table A1-10 of Annex 1.

Because the downlink is PFD limited, increasing the channel bandwidth to 50 kHz or 100 kHz will increase the signal level and $C/(N_0+I_0)$ by 3 and 6 dB respectively. Limiting the service area to ship elevation angles between 10 and 55 degrees also improves the link margin by 3 dB.

The Isoflux antenna improves the link budget at low elevation angles and provides a wider symmetrical coverage area, but requires a 5 times larger transmitter power on the satellite.

The link budget results with a satellite Yagi antenna is shown in Table A[VDESAT]4-65. Isoflux antenna is shown in Table A[VDESAT]4-76.

It should be noted that the analyses based on single satellite visibility.

TABLE A[VDESAT]4-65

Link budget with satellite Yagi antenna (transmit RF power = −12.4 dBW/25 kHz)

Ship elevation angle	Satellite EIRP in circular polarization	Satellite range	Path loss	Polarization loss	Ship antenna gain	Antenna signal level	C/N_0	Noise level in 25 kHz BW	$C/(N_0+I_0)$
(degrees)	(dBW)	(km)	(dB)	(dB)	(dBi)	(dBm)	(dBHz)	(dBm)	(dBHz)
0	−4.4	2 830	145.6	3	3	−120.0	48.4	−116	40.0
10	−4.4	1 932	142.2	3	3	−116.7	51.7	−116	43.3
20	−4.4	1 392	139.4	3	2.5	−114.3	54.1	−116	45.7
30	−4.6	1 075	137.2	3	1	−113.8	54.6	−116	46.2
40	−5.5	882	135.4	3	0	−114.0	54.4	−116	46.0
50	−6.9	761	134.2	3	−1.5	−115.6	52.8	−116	44.4
60	−8.8	683	133.2	3	−3	−118.0	50.4	−116	41.9
70	−11.7	635	132.6	3	−4	−121.3	47.1	−116	38.7
80	−14.6	608	132.2	3	−10	−129.8	38.6	−116	30.2
90	−17.9	600	132.1	3	−20	−143.0	25.4	−116	17.0

TABLE A[VDESAT]4-76

Link budget using Isoflux antenna (transmit RF power = −5.0 dBW/25 kHz)

Ship elevation angle	Sat. EIRP	Path loss	Pol. loss	Ship antenna gain	Ship G/T	C/N_0 no interference	Antenna level	Noise level in 25 kHz	$C/(N_0+I_0)$
deg	dBW	dB	dB	dBi	dB/K	dBHz	dBm	dBm	dBHz
0	−3.0	145.6	3	3	−27.2	49.8	−118.6	−116	41.4
10	−3.5	142.2	3	3	−27.2	52.7	−115.7	−116	44.2
20	−4.0	139.4	3	2.5	−27.7	54.5	−113.9	−116	46.1
30	−5.5	137.2	3	1	−29.2	53.7	−114.7	−116	45.3
40	−7.0	135.4	3	0	−30.2	53.0	−115.4	−116	44.5
50	−9.0	134.2	3	−1.5	−31.7	50.7	−117.7	−116	42.3
60	−10.0	133.2	3	−3	−33.2	49.2	−119.2	−116	40.8
70	−12.0	132.6	3	−4	−34.2	46.8	−121.6	−116	38.4
80	−13.0	132.2	3	−10	−40.2	40.2	−128.2	−116	31.8
90	−13.5	132.1	3	−20	−50.2	29.8	−138.6	−116	21.4

2.2.2 VDE-SAT uplink link budget

Examples of link budgets for the VDE-SAT uplink are provided in the following sections.

2.2.2.1 Ship station e.i.r.p. vs. elevation angle

For ship station e.i.r.p vs elevation angle, see Annex 1.

2.2.2.2 Satellite antenna gain

Table A[VDESAT]4-87 presents the gain of a 3-element Yagi satellite antenna with a peak gain of 8 dBi as a functon of elevation angle.

TABLE A[VDESAT]4-87

Satellite antenna gain vs. ship elevation angle

Ship elevation angle	Nadir offset angle	Boresight offset angle	Satellite antenna gain
deg.	deg.	deg.	dBi
0	66.1	0	8
10	64.2	1.9	8
20	59.2	6.9	8
30	52.3	13.8	7.8
40	44.4	21.7	6.9
50	36	30.1	5.5
60	27.2	38.9	3.6
70	18.2	47.9	0.7
80	9.1	57	−2.2
90	0	66.1	−5.5

2.2.2.3 Satellite system noise temperature

The satellite noise level at the receiver input is shown in Table A[VDESAT]4-98. Without external interference the system noise temperature is 25.7 dBK.

TABLE A[VDESAT]4-98

Satellite receiver system noise temperature

Antenna noise temperature	200.0	K
Feed losses	1.0	dB
LNA noise figure	2.0	dB
LNA noise temperature	159.7	K
Feedloss noise temp. at LNA	56.1	K
Antenna noise temp. at LNA	158.9	K
System noise temp. at LNA	374.7	K
System noise temp. at LNA	25.7	dBK

2.2.2.4 Uplink C/N_0

The baseline uplink link budget is given in Table A[VDESAT]4-10. It is optimised for 0 degree ship elevation angles.

It can be seen from Table A[VDESAT]4-109 that the C/N_0 is better than 74 dBHz for ship elevation angles between 0 and 65 degrees.

TABLE A[VDESAT]4-109

VDE-SAT Uplink link budget, 6 W ship transmit power

Ship elevation angle	Ship antenna gain	Ship e.i.r.p.	Polarization loss	Range	Path loss	Satellite antenna gain	Satellite G/T	C/N_0
deg	dBi	dBW	dB	km	dB	dBi	dB/K	dBHz
0	3	10.8	3	2 830	145.56	8	−17.6	73.2
10	3	10.8	3	1 932	142.25	8	−17.6	76.5
20	2.5	10.3	3	1 392	139.40	8	−17.6	78.9
30	1	8.8	3	1 075	137.16	7.8	−17.8	79.4
40	0	7.8	3	882	135.44	6.9	−18.7	79.2
50	−1.5	6.3	3	761	134.16	5.5	−20.1	77.6
60	−3	4.8	3	683	133.22	3.6	−22	75.2
70	−4	3.8	3	635	132.58	0.7	−24.9	71.9
80	−10	−2.2	3	608	132.21	-2.2	−27.8	63.4
90	−20	−12.2	3	600	132.09	-5.5	−31.1	50.2

2.2.3 Propagation effects

The received signal level on-board a ship will vary due to a number of factors as shown in Table A[VDESAT]4-110. A Rice distribution with a carrier to multipath (*C*/*M*) ratio of 10 dB and fading bandwidth of 3 Hz is assumed (see Figure A[VDESAT]4-3), however the system shall be adaptable to handle significantly worse and better propagation conditions. Mid-latitude fade depths due to ionospheric scintillation are shown in Table A[VDESAT]4-121.

TABLE A~~[VDESAT]~~4-1~~1~~0

Ionospheric effects for elevation angles of about 30° one-way traversal (derived from Recommendation ITU-R P.531)

Effect	Frequency dependence	0.1 GHz	0.25 GHz	1 GHz
Faraday rotation	$1/f^2$	30 rotations	4.8 rotations	108°
Propagation delay	$1/f^2$	25 µs	4 µs	0.25 µs
Refraction	$1/f^2$	< 1°	< 0.16°	< 0.6′
Variation in the direction of arrival (r.m.s.)	$1/f^2$	20′	3.2′	12″
Absorption (auroral and/or polar cap)	$\approx 1/f^2$	5 dB	0.8 dB	0.05 dB
Absorption (mid-latitude)	$1/f^2$	< 1 dB	< 0.16 dB	< 0.01 dB
Dispersion	$1/f^3$	0.4 ps/Hz	0.026 ps/Hz	0.0004 ps/Hz
Scintillation [(1)]	See Rec. ITU-R.P.531	See Rec. ITU-R P.531	See Rec. ITU-R P.531	> 20 dB peak-to-peak

[*] This estimate is based on a TEC of 1 018 electrons/m², which is a high value of TEC encountered at low latitudes in day-time with high solar activity.

[(1)] Values observed near the geomagnetic equator during the early night-time hours (local time) at equinox under conditions of high sunspot number.

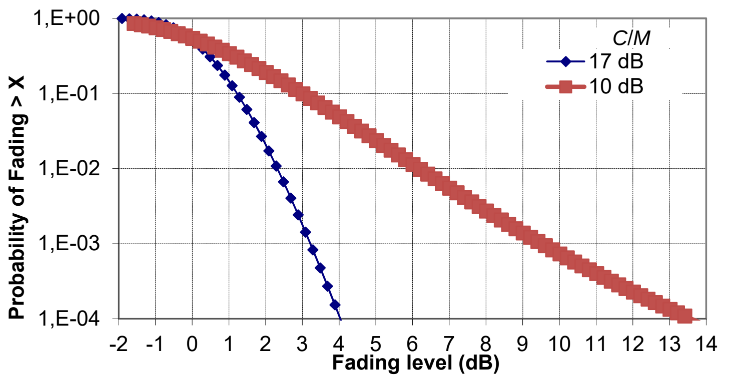
TABLE A~~[VDESAT]~~4-1~~2~~1

Mid-latitude fade depths due to ionospheric scintillation (dB)

Percentage of time (%)	Frequency (GHz)			
	0.1	0.2	0.5	1
1.0	5.9	1.5	0.2	0.1
0.5	9.3	2.3	0.4	0.1
0.2	16.6	4.2	0.7	0.2
0.1	25.0	6.2	1.0	0.3

FIGURE A~~[VDESAT]~~4-3

Ricean fade depth probability



2.3 Protection of the radio astronomy service in the 150.05-153 MHz band from harmful interference from the VDE-SAT downlink

An appropriate protection limit for Radio Astronomy service in the 150.05-153.0 MHz band would be −238 dBW/m^2 in a 2.95 MHz bandwidth centred around 152 MHz. Accordingly the maximum VDE-SAT downlink emission in the 150.05-153 MHz band should be below values shown in Table A~~[VDESAT]4~~-1~~3~~2.

TABLE A~~[VDESAT]4~~-1~~3~~2

Maximum satellite unwanted emissions in the 150.05-153 MHz band

Ship elevation angle (deg)	RAS limit (W/m²/ 2.95 MHz)	Range (km)	Sat. max. interference e.i.r.p.		
			(W)	(dBW)	(dBW/Hz)
0	1.58E-24	2830	1.60E-10	−97.97	−162.67
10	1.58E-24	1932	7.43E-11	−101.29	−165.99
20	1.58E-24	1392	3.86E-11	−104.14	−168.83
30	1.58E-24	1075	2.30E-11	−106.38	−171.08
40	1.58E-24	882	1.55E-11	−108.10	−172.80
50	1.58E-24	761	1.15E-11	−109.38	−174.08
60	1.58E-24	683	9.29E-12	−110.32	−175.02
70	1.58E-24	635	8.03E-12	−110.95	−175.65
80	1.58E-24	608	7.36E-12	−111.33	−176.03
90	1.58E-24	600	7.17E-12	−111.44	−176.14

2.4 Bit mapping

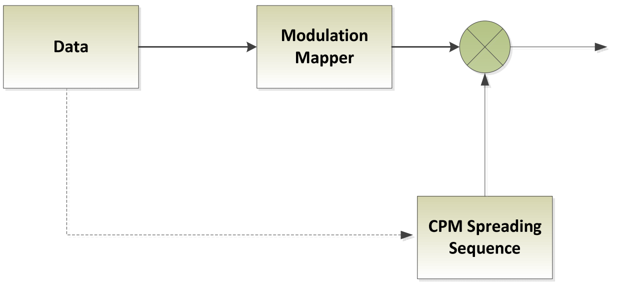
For bit mappings, see Annex 1.

2.5 Spread spectrum with constant envelope

Direct sequence spreading with constant envelope can be implemented according to the spreading strategy {RD-3}. This provides a way to generate constant envelope signals whilst allowing the use of linear modulations (i.e. BPSK, or QPSK for data modulation). In this approach the CPM spreading sequences are selected such that the spread symbols maintain quasi continuous phase even at the transition from one symbol to the next. The CPM spreading principle is provided in Figure~~.~~ A~~41-20~~4.

FIGURE A14-204 –

CPM Spreading Principle



In order to avoid phase discontinuity at the data symbol transitions, the proposed solution is to adapt the spreading sequence to the modulation data. In other words, the CPM spreading sequence at the edge of each symbol is adapted according to the new input modulation symbol value to avoid any phase discontinuity. Such a solution produces a small loss at the receiver as the receiver does not know the edge symbol part of the used CPM spreading sequence. For a spreading factor of 16 or higher, the resulting correlation loss experienced by the receiver due to this issue is less than 0.25 dB. Performance losses with respect to conventional spreading is thus quite negligible provided that SF = 16 or larger is used.

The CPM spreading sequences are computed and optimized off-line and then stored in the memory of the terminals and receivers. A single spreading code is sufficient for all the users in the system. There is thus no need for storing multiple spreading sequences but just a single spreading sequence.

The stored spreading sequence is then applied starting from the preamble and continuing in the data part (as shown in Figure. A14-215). It should be noted that the actual spreading sequence is actually partly dependent on the modulation symbols in order to ensure continuity of the signal phase when the modulation symbol changes (Figure. A14-204). The spread samples are computed on the basis of the current modulation symbol and previous modulation symbol. For QPSK modulation there are 4 possible values for the phase difference of these two symbols. An index from 0 to 3 can point to the possible phase differences and is used to address which of 4 possible spreading sequences is actually used for computing the output signal. Figure A14-226 illustrates the power spectral properties of the proposed modulation scheme (with spreading factor 16). Due to its constant envelope properties, this modulation scheme can operate with a transmit power amplifier operating close to saturation while maintaining a low power leakage to adjacent channels.

FIGURE A41-215

Proposed Spreading in the CPM

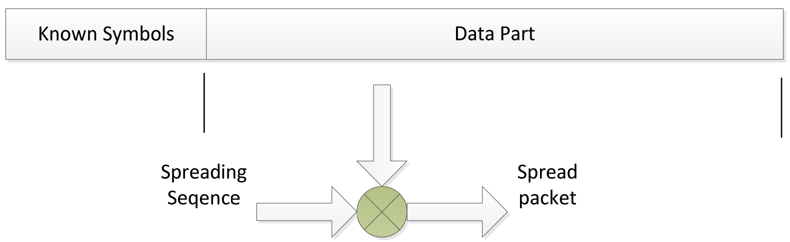
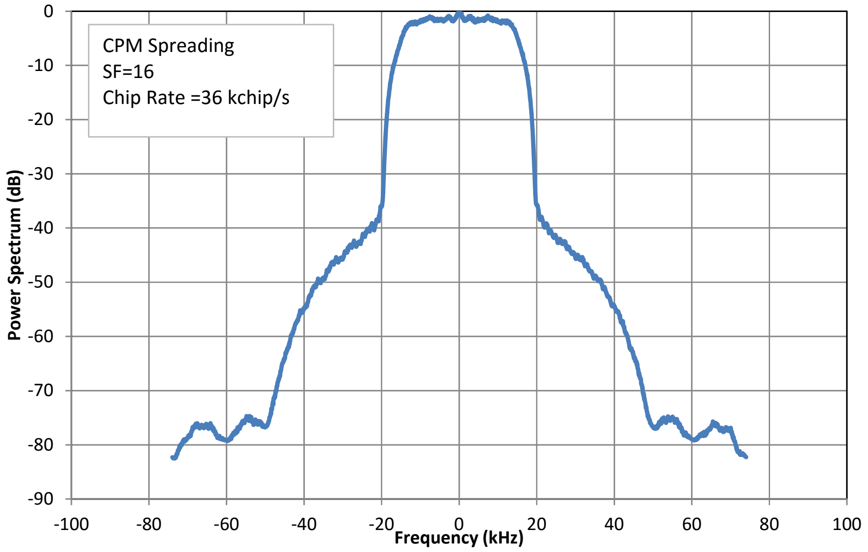


FIGURE A14-6 – 22

Power spectral properties of spread spectrum with constant envelope



2.56 Baseband shaping and quadrature modulation

For baseband shaping of symbols, see Annex 1.

2.76 Transmission timing accuracy

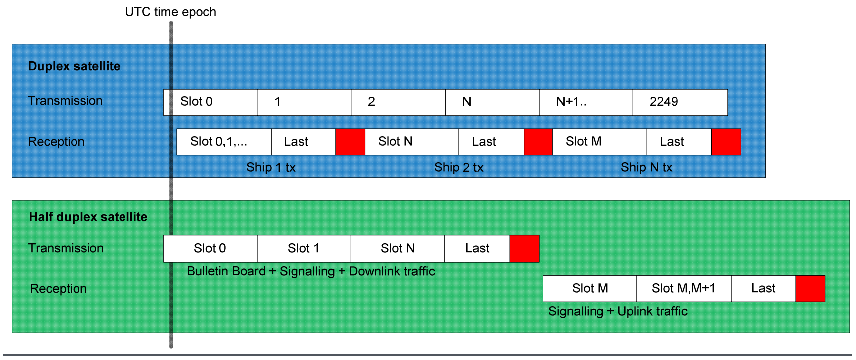
For transmission accuracy figures, see Annex 1.

2.87 Half duplex and full duplex satellites

The system can be configured for both half and full duplex satellites as shown in Figure. A4-67.

FIGURE A[VDESAT]4-67

Half-duplex and full duplex satellite operation



2.98 Frame structure

For frame and transmission burst structure, see Annex 1.

2.109 Forward Error Correction and interleaving

For forward error correction and interleaving, see Annex 1.

2.110 VDE-SAT link configuration formats

For link configurations available for the VDE-SAT uplink and downlink, see Annex 1.

2.12 VDE-SAT Downlink Block Channel Interleaver

A block channel interleaver is considered on the VDE-SAT downlink in order to reduce the impact of the channel short blockage (for example due to the AIS transmission from the vessel or fast fading events). The channel interleaver is applied to the code-words at the output of the encoder.

The interleaver can be applied on data blocks by column permutation (as long as the number of columns can be made as an integer power of 2). The interleaver memory in this case (from the point of view of the transmitter) is written by row and read by columns after having applied an inter-column permutation. The proposed column permutation is resulting from reading the column index in the reverse order (bit shuffling), i.e. the column with index i5 i4, i3 i2, i1, i0 become the column i0, i1,i2, i3, i4, i5, where i0, i1 i2 i3 i4 and i5 are the bits representing a given number.

In more general cases (where the number of columns is not an integer power of 2), the interleaver index can be made available as table-lookup.

3 VDE-SAT link layer

For description of the link layer, see Annex 1.

4 Network layer

For description of the network layer, see Annex 1.

5 Transport layer

For description of the transport layer, see Annex 1.

[Where is Annex 5?]

Annex 6

Commenté [JC94]: No annex 5 – will there be an annex 5?

Resource sharing method for VDES Terrestrial and Satellite Services

1 Introduction

This Annex describes how resource sharing (i.e. in time and frequency) for utilizing the VHF spectrum available between different VDES services and stations should be accomplished.

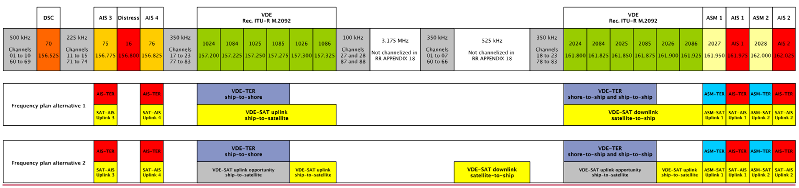
A ship may be within range of multiple controlling shore stations. This annex describes a method for coordinating time and frequency resources between multiple controlling shore stations, particularly the use of bulletin boards and announcement signalling channels, as defined in Annex 1 and 3.

The VDE-SAT is an effective means to extend the VDES to areas outside of coastal VHF coverage. However, due to the large footprint of satellite, the VDE-SAT downlink signal may interfere with VDE-TER in the coastal areas when satellite is in visibility. Similarly, the terrestrial ship-to-shore VDE signals can interfere with the satellite reception of VDE-SAT uplink when a VDE Satellite is in the field of view. The method described in this Annex for resource sharing is derived based on the characteristics of VDE-TER and VDE-SAT, particularly the use of bulletin board and announcement signalling channels, as defined in Annexes 1, 3 and~~,~~ 4 ~~and 5~~.

The channels 24, 84, 25, 85, 26 and 86 are allocated for VDE, with the lower leg frequencies used for ship-to-shore and the upper leg frequencies used for shore-to-ship and ship-to-ship. The channels 2027 (ASM 1) and 2028 (ASM 2) are allocated for ASM. Currently, 2 alternative frequency utilization plans for VDES are under consideration. They describe how resources are allocated and shared between VDE-TER, VDE-SAT and ASM. These 2 alternative frequency utilization plans are illustrated in Figure~~.~~ A6-1, and described further ~~below~~in this section.

FIGURE A6-1

RR APPENDIX 18 and VDES frequency utilization plans



1.1 Frequency plan alternative 1

Frequency plan alternative 1 allow for utilization of the channels 24, 84, 25, 85, 26 and 86 in a shared manner between VDE-TER and VDE-SAT.

– The four channels 1024, 1084, 1025 and 1085 are shared between ship-to-shore and ship-to-satellite (VDE-SAT uplink) services

– The two channels 1026 and 1086 are exclusively reserved for ship-to-satellite (VDE-SAT uplink) services

– The four channels 2024, 2084, 2025 and 2085 are shared among shore-to-ship, ship-to-ship and satellite-to-ship (VDE-SAT downlink) services

– The two channels 2026 and 2086 are exclusively reserved for satellite-to-ship (VDE-SAT downlink) services.

– Two channels 2027(ASM 1) and 2028 (ASM 2) are shared between ship-to-shore, ship-to-ship, shore-to-ship and ship-to-satellite services

1.2 Frequency plan alternative 2

Frequency plan alternative 2 allow for utilization of channels 24, 84, 25 and 85 primarily for VDE-TER, while channels 26 and 86 exclusively reserved for VDE-SAT uplink. VDE-SAT uplink is also possible in channels 24, 84, 25 and 85, but the VDE-SAT uplink in these channels do not impose constraints on VDE-TER. Frequencies are exclusively reserved for VDE-SAT downlink within the frequency range 160.9625 MHz to 161.4875 MHz, which is not channelized in RR Appendix 18.

– The four channels 1024, 1084, 1025 and 1085 are reserved for ship-to-shore services, but ship-to-satellite (VDE-SAT uplink) services are possible without imposing constraints on ship-to-shore services

– The four channels 2024, 2084, 2025 and 2085 are reserved for shore-to-ship and ship-to-ship services, but ship-to-satellite (VDE-SAT uplink) services are possible without imposing constraints on shore-to-ship and ship-to-ship services

– The four channels 1026, 1086, 2026 and 2086 are exclusively reserved for ship-to-satellite (VDE-SAT uplink) services.

– Frequencies are exclusively reserved for satellite-to-ship (VDE-SAT downlink) services within the frequency range 160.9625 MHz to 161.4875 MHz, which is not channelized in RR Appendix 18

– Two channels 2027(ASM 1) and 2028 (ASM 2) are shared between ship-to-shore, ship-to-ship, shore-to-ship and ship-to-satellite services

2 VDES resource sharing principles

2.1 AIS priority

Understanding that when transmissions occurs a VDES mobile station with a single antenna will suffer decreased receiver sensitivity, care must be taken to respect the AIS transmission and reception as the highest priority.

2.2 Coordination between ASM and VDE

VDE ship transmissions should be coordinated with transmissions on the ASM channels to ensure that ASM messages with new safety and navigational related information can be received.

2.3 Shore station VDES control area

The VDES resource assignments in the proximity of a shore station is monitored and controlled by a shore station. Shore stations utilize terrestrial bulletin board (TBB) and announcement signalling channels (ASC) to coordinate the resource assignment within the control area. The shore station may incorporate information regarding VDE satellite communications within the TBB and ASC. The shore station may acquire the VDE satellite information directly from the VDE-Satellite downlink (the satellite bulletin board and ASC) or in coordination with the satellite service providers.

There are dedicated slots and frequency bands for TBB and ASC that are reserved to communicate the required information to each vessel in the control area of a shore station. The default (or initial) assignment are described in ~~Section~~§ 4 of this Annex.

2.4 VDE-SAT resource assignment

Each satellite should use bulletin board and announcement channels (as defined in Annex 1 and 4) to communicate the VDE-SAT resource assignments (both downlink and uplink) to vessels in the coverage area.

There are dedicated slots and frequency bands for the satellite bulletin board and announcement channels that are reserved to communicate the required information to each vessel in the field of view of a satellite.

Since the satellite coverage may include several shore station control areas, the VDE-SAT resource assignment should respect all requirements of shore control areas that are within the field of view at any given time. Within each satellite orbit the information regarding the resource assignment should be updated according to the shore station control areas in the satellite field of view.

A default (or initial) VDE-SAT resource allocation is defined in § 4 below to serve as the starting point for the resource sharing.

3 VDE-TER Resource sharing between multiple controlling shore stations

The allocation of frequency and time slots used for the bulletin board announcement must be coordinated between controlling stations. Other resource assignments are managed based on the content of the bulletin board and announcement signalling channels. The assignment may change dynamically (according to temporal demands).

There are dedicated resources in channel 2024 and 2084 that are assigned to the terrestrial bulletin board and announcement channels, as described in Annex 1 and 3.

Channels 2024, 2084, 2025 and 2085 are shared between multiple controlling stations. The resource sharing must be coordinated between shore station operators. This coordination can be done either directly between the operators or rely on the bulletin board and announcement channels of the shore stations, depending on the shore control areas, the resource assignment may vary. As an initial configuration for resource sharing, the controlling shore stations should adopt a static assignment in time and frequency.

4 VDE-TER and VDE-SAT downlink resource sharing

4.1 Resource sharing with frequency plan alternative 1

With frequency plan alternative 1, the channels 2026 and 2086 are dedicated to VDE-SAT downlink. Within these exclusive VDE-SAT channels, there are dedicated time slots that are assigned to the satellite bulletin board and announcement signalling channels as described in Annex 1 and 4. Other slot assignments in the exclusive VDE-SAT frequency bands are managed based on the content of the bulletin board and announcement signalling channels. The assignment may change dynamically (according to the satellite coverage or temporal demands).

Channels 2024, 2084, 2025 and 2085 are shared between VDE-SAT Downlink and VDE-TER. Depending on the satellite coverage area and the shore control areas, the resource assignment may vary.

There are dedicated time slots in channel 2024 and 2084 that are assigned to the terrestrial signalling channel and terrestrial bulletin board, as described in Annex 1 and 3. These slots should not be used by VDE-SAT downlink when a VDE shore station is within the satellite coverage area.

A shore station may assign the full resources of channels 2024, 2084, 2025 and 2085 for terrestrial services when there is no transmitting VDE satellite in the field of view.

When a transmitting VDE satellite is in the field of view the resource sharing between VDE-SAT downlink and VDE shore-to-ship and ship-to-ship must be coordinated between the shore operator and the satellite operator. This coordination can be done either directly between the operators or rely on the bulletin board and announcement channels of the satellite and shore stations. As an initial configuration for resource sharing, a static assignment in time and frequency should be adopted by the terrestrial and satellite entities.

– Channels 2024 and 2084 are exclusively used for terrestrial VDE, maintaining the original signalling assignment that was described above
– Channels 2026 and 2086 are exclusively used for VDE-SAT downlink, maintaining the original signalling assignment that was described above
– Channels 2025 and 2085 are time-shared between VDE-SAT downlink and VDE terrestrial services. The time sharing is based on time intervals of 2.4 s (90 slots) that are assigned periodically to VDE-SAT and VDE terrestrial services

As the starting point of VDES resource sharing or in the absence of coordination between the shore and satellite operation, this resource sharing method should be used.

Coordination of resource sharing between VDE ship-to-ship and VDE-SAT downlink for areas not controlled by a VDE shore station is managed by the VDE-SAT bulletin board, as described in Annex 4. As a starting point for this resource sharing or in the absence of any VDE-SAT bulletin board, the resource sharing method described above should be used.

4.2 Resource sharing with frequency plan alternative 2

With frequency plan alternative 2, the frequency band from 160.9625 MHz to 161.4875 MHz is dedicated to VDE-SAT downlink. The frequencies in this band are not channelized in RR APPENDIX 18. Within this exclusive VDE-SAT band, there are dedicated channels and time slots that are assigned to the satellite bulletin board and announcement signalling channels as described in Annex 1 and 4. Other slot assignments in this exclusive VDE-SAT frequency band are managed based on the content of the bulletin board and announcement signalling channels. The assignment may change dynamically (according to the satellite coverage or temporal demands).

5 Sharing between different VDE satellite systems

The sharing between two or more satellite systems is coordinated between the satellite operators and organized through the bulletin board, delivered by satellites in VDE-SAT downlink band, as described in Annex 1 and 4. Ships use the satellite bulletin boards for channel and resource configuration.

The waveform used for the bulletin board should allow for detection of overlapping signals received from multiple satellites. The use of direct sequence spreading as defined in Annex 4 allows for detection of up to 8 overlapping satellite signals.

6 VDE-TER and VDE-SAT uplink resource sharing

6.1 Resource sharing with frequency plan alternative 1

With frequency plan alternative 1, the lower frequency bands, channel 1026 and 1086 are dedicated to VDE-SAT uplink while channels 1024, 1084, 1025 and 1085 are shared between VDE-TER and VDE-SAT.

The exclusive VDE-SAT uplink channels may be used for dedicated (demand assigned) or random access to satellite. Since there is no VDE terrestrial interference on these two channels, these channels should be used for higher priority message (safety, distress, acknowledgement, etc.).

Through the bulletin board, a shore station may assign the full resources of channels 1024, 1084, 1025 and 1085 for terrestrial services when there is no receiving VDE satellite in the field of view.

When a transmitting VDE satellite is in the field of view the resource sharing between VDE-SAT uplink and VDE-TER ship-to-shore must be coordinated between the shore operator and the satellite operator. This coordination can be done either directly between the operators or rely on the bulletin board and announcement channels of the satellite and shore stations. As an initial configuration for resource sharing, a static assignment in time and frequency should be adopted by the terrestrial and satellite entities.

– Channels 1024 and 1084 are exclusively used for VDE-TER ship-to-shore
– Channels 1026 and 1086 are exclusively used for VDE-SAT uplink (ship-to-satellite)
– Channels 1025 and 1085 are time-shared between the VDE-SAT uplink and VDE-TER services. The time-sharing is based on time intervals of 1 hexslot (6 slots) that are assigned alternately to VDE-SAT and VDE-TER services

As the starting point of VDES resource sharing or in the absence of coordination between the shore and satellite operation, this resource sharing method should be used.

6.2 Resource sharing with frequency plan alternative 2

With frequency plan alternative 2, the utilization of channels 24, 84, 25 and 85 is primarily for VDE-TER. VDE-SAT uplink is also possible in channels 24, 84, 25 and 85, but the VDE-SAT uplink in these channels do not impose constraints on VDE-TER and should only use resources not reserved by VDE-TER.

Channels 26 and 86 exclusively reserved for VDE-SAT uplink. Therefore, on these channels no resources are shared and no sharing scheme is required.

Annex 4

Technical characteristics of VDE satellite downlink in the VHF maritime mobile band

1 Introduction

This Annex describes the characteristics of the satellite downlink of the VHF Data Exchange System (VDES) according to the identified requirements.

In particular, VDE satellite downlink is assumed to support the following services:

– Downlink multicast multi-packet data transfer

– Shore originated unicast multi-packet data transfer via satellite.

In this Annex, Low Earth Orbit (LEO) satellites with 600 km altitude are considered to present typical examples of VDE satellite downlink solutions. It should be noted that other orbital selections are also possible according to the overall system design consideration.

The focus of this Annex is to describe the four lower layers of the OSI model (as defined in Annex 1): the physical, the link, the network and the transport layers.

2 VDE-SAT downlink physical layer

2.1 VDE-SAT downlink key parameters

This section outlines assumptions regarding the VDE-SAT downlink system parameters that are used as representative examples in this Annex.

2.1.1 Satellite to surface distance range

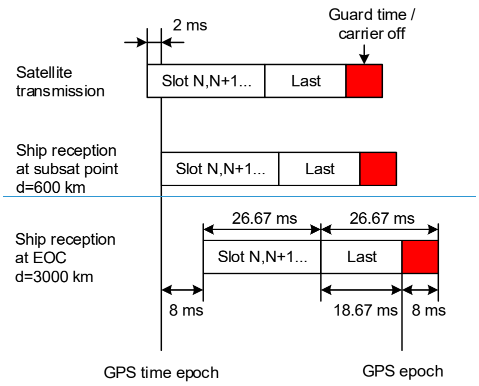
The orbit height determines the satellite range variations. For example, for a 600 km LEO the maximum range is 2 830 km. For timing purposes a maximum range of 3 000 km will be used.

The minimum range is equal to the orbit height. For a LEO satellite at 600 km altitude the minimum range will be 600 km. This value is used to determine the minimum propagation delay time. Considering these exemplary values for the minimum and maximum ranges, the path delay will vary from 10 ms to 2 ms, a variation of 8 ms as shown in Fig. A4-1.

In addition to the relative delays between signal receptions at a vessel from different satellites, there could be absolute delay due to other sources such as signal processing delay. The satellite service provider should pre-compensate for absolute delay.

FIGURE A4-1

Downlink guard timing



2.1.2 Carrier frequency error

The frequency error is the sum of the satellite transmission frequency error and Doppler and the frequency uncertainty at the receiver. The transmit frequency error at the satellite shall be less than 1 ppm, i.e. ±160 Hz.

A LEO satellite will move at a speed of about 8 km/s and this will cause a maximum Doppler of ±4 kHz at VHF.

2.1.3 Downlink link budget analyses

The link C/N_0 is determined by the satellite e.i.r.p. path losses, propagation losses, receiver sensitivity/figure of merit and local interference levels. Examples of link budget analyses are provided in the following sections.

2.1.4 Satellite downlink e.i.r.p.

The e.i.r.p. can be derived from PFD mask given in Table A4-1.

TABLE A4-1

Proposed power spectral and PFD mask

$$\theta^\circ = earth - satellite\ elevation\ angle$$

$$PFD(\theta^\circ)_{(\mathrm{dBW/(m^2*4\,kHz)})} = \begin{cases} -149 + 0.16 * \theta^\circ & 0^\circ \leq \theta < 45^\circ; \\ -142 + 0.53 * (\theta^\circ - 45^\circ) & 45^\circ \leq \theta < 60^\circ; \\ -134 + 0.1 * (\theta^\circ - 60^\circ) & 60^\circ \leq \theta \leq 90^\circ. \end{cases}$$

Table A4-2 shows the theoretical maximum satellite e.i.r.p. as a function of elevation angles for this mask.

TABLE A4-2

Satellite maximum e.i.r.p. vs. elevation angle

Ship Elevation angle θ	Powerflux density on ground	Satellite range	Maximum downlink satellite e.i.r.p.
(degrees)	(dBW/m²/4 kHz)	(km)	(dBW in 25 kHz)
0	−149.0	2 831	−1.0
10	−147.4	1 932	−2.7
20	−145.8	1 392	−4.0
30	−144.2	1 075	−4.6
40	−142.6	882	−4.7
50	−139.4	761	−2.8
60	−134.0	683	1.6
70	−133.0	635	2.0
80	−132.0	608	2.6
90	−131.0	600	3.5

2.1.5 Satellite e.i.r.p. vs. elevation

Most of the satellite coverage area and visibility time will be at low elevation angles, and high elevation angle coverage may be sacrificed without significant system capacity loss.

The following two satellite antennas have been analysed and are acceptable.

1) Yagi Antenna: For this antenna the link budget is optimised for 0 degrees ship elevation angle using a three element Yagi antenna with the satellite pointed at the horizon is given in Table A4-3. Assuming a peak antenna gain of 8 dBi, a transmit RF power of −12.4 dBW in 25 kHz will ensure compliance with the PFD limit. Satellite e.i.r.p. vs. ship elevation is shown in Table A4-3.

TABLE A4-3

Satellite e.i.r.p. vs. elevation using a Yagi antenna

Ship elevation angle	Nadir offset angle	Boresight offset	Satellite antenna gain	Satellite e.i.r.p. in circular polarization	Satellite range	PFD	Table A4-1 PFD limit	PFD margin
degrees	degrees	degrees	dBi	dBW	km	dBW/m²/4 kHz	dBW/m²/ 4 kHz	dB
0	66.1	0	8	−4.4	2 830	−152.4	−149.0	3.4
10	64.2	1.9	8	−4.4	1 932	−149.1	−147.4	1.7
20	59.2	6.9	8	−4.4	1 392	−146.2	−145.8	0.4
30	52.3	13.8	7.8	−4.6	1 075	−144.2	−144.2	0.0
40	44.4	21.7	6.9	−5.5	882	−143.4	−142.6	0.8
50	36	30.1	5.5	−6.9	761	−143.5	−139.4	4.1

TABLE A4-3 (*end*)

Ship elevation angle	Nadir offset angle	Boresight offset	Satellite antenna gain	Satellite e.i.r.p. in circular polarization	Satellite range	PFD	Table A4-1 PFD limit	PFD margin
degrees	degrees	degrees	dBi	dBW	km	dBW/m²/4 kHz	dBW/m²/ 4 kHz	dB
60	27.2	38.9	3.6	−8.8	683	−144.5	−134.0	10.5
70	18.2	47.9	0.7	−11.7	635	−146.7	−133.0	13.7
80	9.1	57	−2.2	−14.6	608	−149.2	−132.0	17.2
90	0	66.1	−5.5	−17.9	600	−152.4	−131.0	21.4

2) Isoflux antenna: This antenna is designed to point at the nadir direction providing a symmetric radiation pattern around the pointing direction. Assuming a peak antenna gain of 2 dBi, a transmit RF power of −5 dBW in 25 kHz will ensure compliance with the PFD limit. Satellite e.i.r.p. vs. ship elevation is shown in Table A4-4.

TABLE A4-4

Satellite e.i.r.p vs. elevation using an isoflux antenna

Ship elevation angle	Nadir offset angle	Boresight offset	Satellite antenna gain	Satellite e.i.r.p. in circular polarization	Satellite range	PFD	Table A4-1 PFD limit	PFD margin
degrees	degrees	degrees	dBi	dBW	km	dBW/m²/4 kHz	dBW/m²/4 kHz	dB
0	66.1	0	2	−3.0	2 830	−151.0	−149.0	2.0
10	64.2	1.9	1.5	−3.5	1 932	−148.2	−147.4	0.8
20	59.2	6.9	1	−4.0	1 392	−145.8	−145.8	0.0
30	52.3	13.8	−0.5	−5.5	1 075	−145.1	−144.2	0.9
40	44.4	21.7	−2	−7.0	882	−144.9	−142.6	2.3
50	36	30.1	−4	−9.0	761	−145.6	−139.4	6.2
60	27.2	38.9	−5	−10.0	683	−145.7	−134.0	11.7
70	18.2	47.9	−7	−12.0	635	−147.0	−133.0	14.0
80	9.1	57	−8	−13.0	608	−147.6	−132.0	15.6
90	0	66.1	−8.5	−13.5	600	−148.0	−131.0	17.0

2.1.6 Protection of the radio astronomy service in the 150.05-153 MHz band

An appropriate protection limit for Radio Astronomy service in the 150.05-153.0 MHz band would be −238 dBW/m² in a 2.95 MHz bandwidth centred around 152 MHz. Accordingly the maximum VDE-SAT downlink emission in the 150.05-153 MHz band should be below values shown in Table A4-5.

TABLE A4-5

Maximum satellite unwanted emissions in the 150.05-153 MHz band

Ship elevation angle (deg)	RAS limit (W/m²/ 2.95 MHz)	Range (km)	Sat. max. interference e.i.r.p.		
			(W)	(dBW)	(dBW/Hz)
0	1.58E-24	2830	1.60E-10	–97.97	–162.67
10	1.58E-24	1932	7.43E-11	–101.29	–165.99
20	1.58E-24	1392	3.86E-11	–104.14	–168.83
30	1.58E-24	1075	2.30E-11	–106.38	–171.08
40	1.58E-24	882	1.55E-11	–108.10	–172.80
50	1.58E-24	761	1.15E-11	–109.38	–174.08
60	1.58E-24	683	9.29E-12	–110.32	–175.02
70	1.58E-24	635	8.03E-12	–110.95	–175.65
80	1.58E-24	608	7.36E-12	–111.33	–176.03
90	1.58E-24	600	7.17E-12	–111.44	–176.14

2.1.7 Receive antenna gain

Refer to Annex 1.

2.1.8 Received signal to noise plus interference level

Refer to Annex 1.

2.1.9 Link $C/(N_0+I_0)$

The nominal signal level and $C/(N_0+I_0)$ vs. elevation for a 25 kHz channel are provided in Table A4-3 and Table A4-4 for Yagi and Isoflux on-board antennas. The assumed ship antenna gain is 3 dBi and the system noise temperature is 30.2 dBK as shown in Table A1-5 (Annex 1).

Because the downlink is PFD limited, increasing the channel bandwidth to 50 kHz or 100 kHz will increase the signal level and $C/(N_0+I_0)$ by 3 and 6 dB respectively. Limiting the service area to ship elevation angles between 10 and 55 degrees also improves the link by 3 dB.

The Isoflux antenna improves the link budget at low elevation angles and provides a wider symmetrical coverage area, but requires a 5 times larger transmitter power on the satellite.

The link budget results with a satellite Yagi antenna is shown in Table A4-6. Isoflux antenna is shown in Table A4-7A.

It should be noted that the analyses based on single satellite visibility.

TABLE A4-6

Link budget with satellite Yagi antenna (transmit RF power = −12.4 dBW/25 kHz)

Ship elevation angle	Satellite EIRP in circular polarization	Satellite range	Path loss	Polarization loss	Ship antenna gain	Antenna signal level	C/N_0	Noise level in 25 kHz BW	$C/(N_0+I_0)$
(degrees)	(dBW)	(km)	(dB)	(dB)	(dBi)	(dBm)	(dBHz)	(dBm)	(dBHz)
0	−4.4	2 830	145.6	3	3	−120.0	48.4	−116	40.0
10	−4.4	1 932	142.2	3	3	−116.7	51.7	−116	43.3
20	−4.4	1 392	139.4	3	2.5	−114.3	54.1	−116	45.7
30	−4.6	1 075	137.2	3	1	−113.8	54.6	−116	46.2
40	−5.5	882	135.4	3	0	−114.0	54.4	−116	46.0
50	−6.9	761	134.2	3	−1.5	−115.6	52.8	−116	44.4
60	−8.8	683	133.2	3	−3	−118.0	50.4	−116	41.9
70	−11.7	635	132.6	3	−4	−121.3	47.1	−116	38.7
80	−14.6	608	132.2	3	−10	−129.8	38.6	−116	30.2
90	−17.9	600	132.1	3	−20	−143.0	25.4	−116	17.0

TABLE A4-7A

Link budget using Isoflux antenna (transmit RF power = −5.0 dBW/25 kHz)

Ship elevation angle	Sat. EIRP	Path loss	Pol. loss	Ship antenna gain	Ship G/T	C/N_0 no interference	Antenna level	Noise level in 25 kHz	$C/(N_0+I_0)$
deg	dBW	dB	dB	dBi	dB/K	dBHz	dBm	dBm	dBHz
0	−3.0	145.6	3	3	−27.2	49.8	−118.6	−116	41.4
10	−3.5	142.2	3	3	−27.2	52.7	−115.7	−116	44.2
20	−4.0	139.4	3	2.5	−27.7	54.5	−113.9	−116	46.1
30	−5.5	137.2	3	1	−29.2	53.7	−114.7	−116	45.3
40	−7.0	135.4	3	0	−30.2	53.0	−115.4	−116	44.5
50	−9.0	134.2	3	−1.5	−31.7	50.7	−117.7	−116	42.3
60	−10.0	133.2	3	−3	−33.2	49.2	−119.2	−116	40.8
70	−12.0	132.6	3	−4	−34.2	46.8	−121.6	−116	38.4
80	−13.0	132.2	3	−10	−40.2	40.2	−128.2	−116	31.8
90	−13.5	132.1	3	−20	−50.2	29.8	−138.6	−116	21.4

2.1.10 Propagation effects

The received signal level on-board a ship will vary due to a number of factors as shown in Table A4-7. A Rice distribution with a carrier to multipath (*C*/*M*) ratio of 10 dB and fading bandwidth of 3 Hz is assumed (see Fig. A4-2), however the system shall be adaptable to handle significantly worse and better propagation conditions. Mid-latitude fade depths due to ionospheric scintillation are shown in Table A4-8.

TABLE A4-7

Ionospheric effects for elevation angles of about 30° one-way traversal (derived from Recommendation ITU-R P.531)

Effect	Frequency dependence	0.1 GHz	0.25 GHz	1 GHz
Faraday rotation	$1/f^2$	30 rotations	4.8 rotations	108°
Propagation delay	$1/f^2$	25 μs	4 μs	0.25 μs
Refraction	$1/f^2$	< 1°	< 0.16°	< 0.6′
Variation in the direction of arrival (r.m.s.)	$1/f^2$	20′	3.2′	12″
Absorption (auroral and/or polar cap)	$\approx 1/f^2$	5 dB	0.8 dB	0.05 dB
Absorption (mid-latitude)	$1/f^2$	< 1 dB	< 0.16 dB	< 0.01 dB
Dispersion	$1/f^3$	0.4 ps/Hz	0.026 ps/Hz	0.0004 ps/Hz
Scintillation (1)	See Rec. ITU-R P.531	See Rec. ITU-R P.531	See Rec. ITU-R P.531	> 20 dB peak-to-peak

* This estimate is based on a TEC of 1 018 electrons/m², which is a high value of TEC encountered at low latitudes in day-time with high solar activity.

(1) Values observed near the geomagnetic equator during the early night-time hours (local time) at equinox under conditions of high sunspot number.

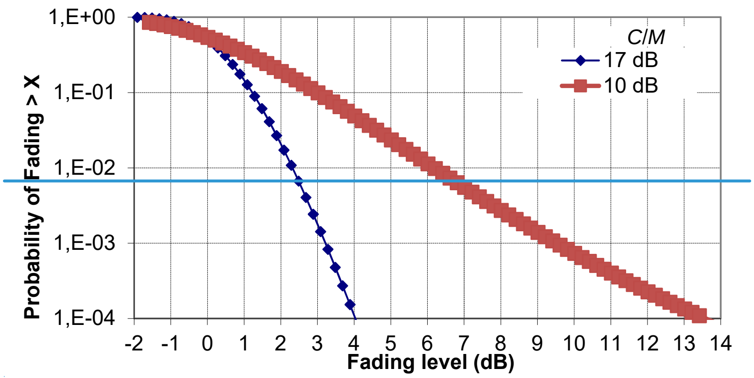
TABLE A4-8

Mid-latitude fade depths due to ionospheric scintillation (dB)

Percentage of time (%)	Frequency (GHz)			
	0.1	0.2	0.5	1
1.0	5.9	1.5	0.2	0.1
0.5	9.3	2.3	0.4	0.1
0.2	16.6	4.2	0.7	0.2
0.1	25.0	6.2	1.0	0.3

FIGURE A4-2

Ricean fade depth probability



2.2 Physical layer modulation schemes

VDE-SAT Downlink supports different modulation to maximise spectral efficiency and throughput. The supported modulation methods are given in Table A4-9.

TABLE A4-9

Downlink modulation methods

Index	Bits/symbol	Modulation type	Bit mapping
1	1	BPSK	–
2	2	Gray encoded QPSK	Figure A4-3
3	3	Gray encoded 8PSK	Figure A4-4
4	4	16APSK	Figure A4-5

FIGURE A4-3

QPSK symbol to bit mapping

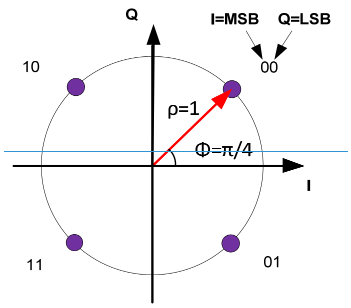


FIGURE A4-4

8PSK symbol to bit mapping

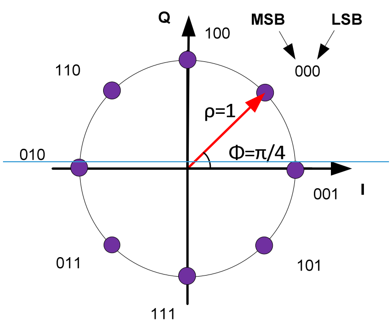
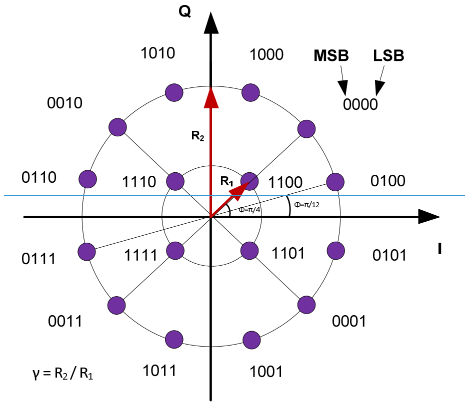


FIGURE A4-5

16APSK bit to symbol mapping



The 16 APSK modulation constellation is composed of two concentric rings of uniformly spaced 4 and 12 PSK points, respectively in the inner ring of radius R_1 and outer ring of radius R_2.

The ratio of the outer circle radius to the inner circle radius ($\gamma = R_2/R_1$) shall be equal to 3. R_1 shall be set to $1/\sqrt{7}$, R_2 shall be set to $3/\sqrt{7}$ in order to have the average signal energy equal to 1.

Similar to AIS, when data is output on the VHF data link it should be grouped in bytes of 8 bits from top to bottom of the table associated with each message in accordance with ISO/IEC 13239:2002. Each byte should be output with least significant bit first.

2.3 Baseband shaping and quadrature modulation

The baseband symbols shall be squared root raised cosine filtered. The roll-off factor should be = 0.25.

2.4 Transmission accuracy figures

2.4.1 Symbol timing accuracy (at the output of satellite)

The timing accuracy of the transmit signal at the satellite should be better than 5 ppm.

2.4.2 Transmitter timing jitter

The timing jitter should be better than 5% of the symbol interval (peak value).

2.4.3 Slot transmission accuracy at the satellite output

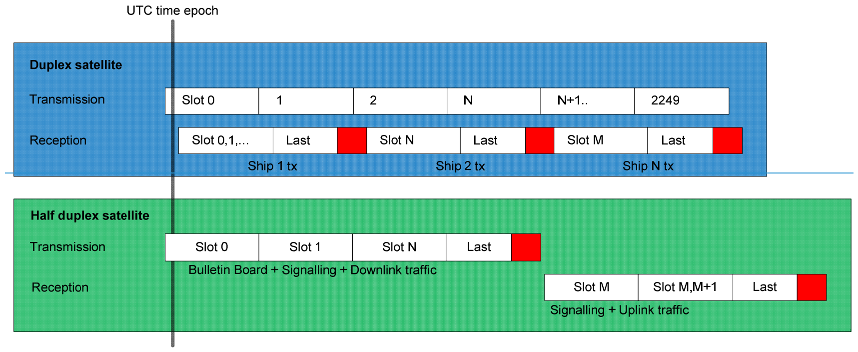
The slot transmission accuracy should be better than 50 µs (peak) relative for example to GNSS reference timing.

2.5 Half duplex and full duplex satellites

The system can be configured for both half and full duplex satellites as shown in Fig. A4-6.

FIGURE A4-6

Half-duplex and full duplex satellite operation



2.6 Frame hierarchy

The VDES frame structure is identical and synchronized in time on the Earth's surface to UTC (as in AIS). The frame hierarchy is shown in Fig. A4-7.

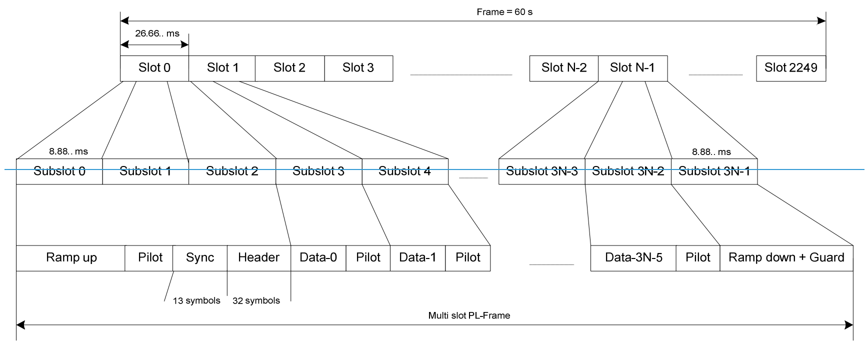
As shown in Fig. A4-7, each frame consists of 2 250 slots (similar to Recommendation ITU-R M.1371).

Frame 0 starts at 00:00:00 UTC, and there are 1 440 frames in a day. The impact of leap second adjustments should be accounted for to avoid any propagation of error.

The number of sub slots per PL-Frame is encoded within its header (as described in the following sections).

FIGURE A4-7

VDE-SAT downlink frame hierarchy



2.6.1 Guard time and ramp up

For ramp up and genernal packet structure, see Annex 1, § 3.3The ramp up time from −30 dBc to −1.5 dBc of the power shall occur in less than or equal to 300 µs for 50 kHz channel occupancy. This is a means to maintain compliancy with the adjacent channel interference requirements.

The guard time at the beginning of a PL-Frame may not be required, but has been provided to allow for future expansion of the pilot, synchronization word and the PL-Frame format header.

2.6.2 Synchronization pilot

Synchronization pilot is a set of known symbols before the synchronization word and at regular intervals during the data portion.

2.6.3 Synchronization (SYNC) word

For general information on training sequence, see Annex 1, § 3.3

The PL-Frame synchronization word and header format is fixed for all transmissions. The 13 bit Barker code unique word is defined in Table A4-10. It is modulated with BPSK at a symbol rate of 2.4 ksym/s. Bit 0 is transmitted first. The duration is 4.91 ms.

TABLE A4-10

Barker sequence unique word

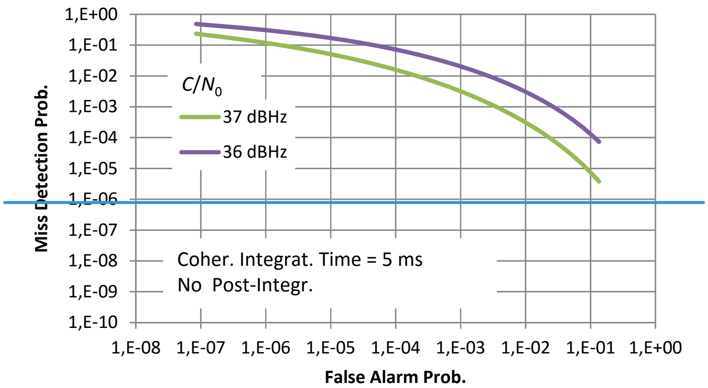
Bit number												
0	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	1	–1	–1	1	1	–1	1	–1	1

The missed detection and false detection probabilities are shown in Figure A4-8 for a $C/(N_0+I_0)$ of 37 dBHz. For a 50 kHz channel, this corresponds to a fade depth of 7 dB, which occurs less than 1% of the time for the Ricean channel (C/M = 10 dB).

During these short periods a constant false alarm rate threshold set to 10^{-4} will result in 2% of PL-Frame not detected during the fading events.

FIGURE A4-8

SYNC word loss and false detection probabilities



2.6.4 Direct sequence spreading

The spreading codes SS0 and SS1 are selected to minimize the maximum "undesired correlation" as defined below:

– Self correlation of the code with its time delayed version

– Correlations of the code with other sequences.

The evaluation is carried out not only for frequency-aligned signals, but also for signals with Doppler difference.

The selected codes are SS0 and SS1 as shown in Table A4-11.

The first pilot and BPSK symbols are spread using an 8 bit sequence to a chip rate of 19.2 kchip/s to fit in a 50 kHz channel. Spreading sequence SS0 from Table A4-11 is used.

TABLE A4-11

Spreading sequences

Sequence name	Chip number							
	0	1	2	3	4	5	6	7
SS0 (0b1001010)	1	–1	–1	–1	1	–1	1	–1
SS1 (0b10100011)	1	–1	1	–1	–1	–1	1	1
SS2 (0b01101100)	–1	1	1	–1	1	1	–1	–1
SS3 (0b 01111001)	–1	1	1	1	1	–1	–1	1

2.6.5 PL-Frame header

For general information on frame structure, see Annex 1, § 3.3

The header is BPSK modulated and spread the same way as the synchronization word described above. This PL-Frame header defines the following parameter associated with the each PL-Frame:

PL-Frame duration (as an integer multiple of a sub slot duration)

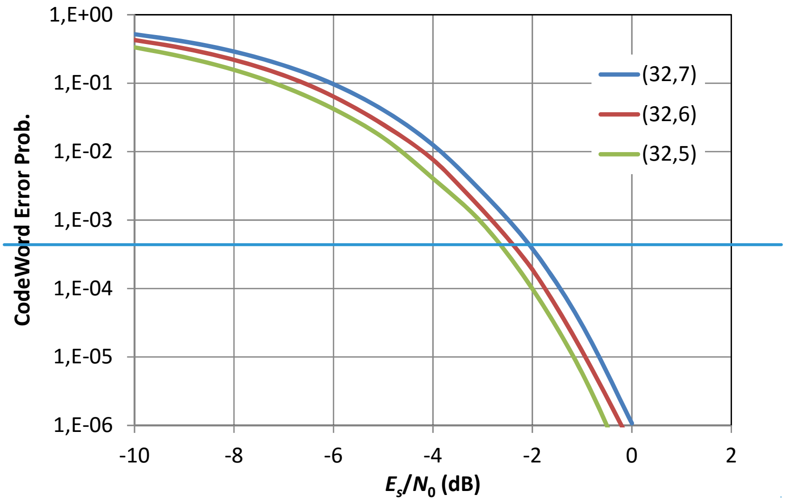
Number of data sub slots (N) per PL-Frame:

– Symbol rate
– Modulation type
– FEC type
– FEC rate
– Interleaver type
– Scrambler type
– Spreading Factor (1 or higher)
– Spreading sequence (1 or as defined).

The header provides 7 bits to define up to 128 PL-Frame formats. The PL-Frame header is encoded using (32,7) quad-orthogonal forward error correction coding. The performance of this FEC is shown in Fig. A4-9.

FIGURE A4-9

Header error probability



2.6.6 Data segment forward error correction coding

The FEC coding scheme applied to the data segment of PL-Frames is similar to the FEC code of the 3GPP standard. The definition of the FEC is Annex 1 since a common FEC scheme is applicable to VDE-SAT and VDE-terrestrial.

2.6.7 Data segments

As shown in the frame hierarchy, each PL-Frame includes one or several data segments. Data segments contain channel symbols that carry encoded information bits. In each PL-Frame, the encoded bits are mapped into segment of *N* of interleaved data.

2.6.8 Physical layer scrambling

Prior to modulation (and spreading if applicable), each PL-Frame samples, excluding the SYNC word, should be randomized for energy dispersal by multiplying the (I + jQ) samples by a complex randomization sequence ($C_I + jC_Q$):

$I_{SCRAMBLED} = (I\ C_I - Q\ C_Q)$

$Q_{SCRAMBLED} = (I\ C_Q + Q\ C_I)$.

The randomization sequence rate corresponds to the PL-Frame symbol rate, thus it has no impact on the occupied signal bandwidth. The randomization sequence shall be reinitialized at the end of each PL-Frame. The randomization sequence length should be truncated to the length of the PL-Frame (excluding the SYNC word).

The scrambling code sequence should be pre-defined according to the PL-Frame format.

2.6.9 Channel interleaver

A block channel interleaver is considered on the VDE-SAT downlink in order to reduce the impact of the channel short blockage (for example due to the AIS transmission from the vessel or fast fading events). The channel interleaver is applied to the code-words at the output of the encoder.

The interleaver can be applied on data blocks by column permutation (as long as the number of columns can be made as an integer power of 2). The interleaver memory in this case (from the point of view of the transmitter) is written by row and read by columns after having applied an inter-column permutation. The proposed column permutation is resulting from reading the column index in the reverse order (bit shuffling), i.e. the column with index i_5 i_4, i_3, i_2, i_1, i_0 become the column i_0, i_1, i_2, i_3, i_4, i_5, where i_0, i_1, i_2, i_3, i_4 and i_5 are the bits representing a given number.

In more general cases (where the number of columns is not an integer power of 2), the interleaver index can be made available as table lookup.

2.6.10 Ramp down

For general information on the ramp down, see Annex 1, § 3.3

The ramp down occurs in the last sub slot of each PL-Frame (as shown in Fig. A4-7) followed by the guard time. The overall duration of the ramp down and guard time is 8.88 ms (one sub slot duration) while the ramp down time from 90% to 10% of the power should occur in less than 300 µs.

2.6.11 Guard time

The guard time is added to the end of each PL-Frame to avoid overlapping with VDES terrestrial transmissions. The guard time duration is 8.88 ms corresponding to one sub-slot duration. This time is adequate to cover the differential delay between the shortest and the longest propagation time within the coverage area of a LEO satellite at 600 km altitude (or lower).

2.7 VDE-SAT downlink PL-Frame formats

As illustrated in Fig. A4-7, PL-Frames are the self-contained transmission units used for the VDE-SAT downlink and uplink. This section defines several PL-Frame formats that are used for signalling and data transmission on the VDE-SAT downlink channels. Based on the PL-Frame header, it is possible to define 128 distinct PL-Frame formats for the VDE-SAT downlink and uplink.

2.7.1 PL-Frame format 1

The PL-Frame format 1 is provided in Table A4-12.

TABLE A4-12

PL-Frame Format 1

Downlink format	1	
Function	Multiple access, reliable one way transmission	
Usage	Bulletin Board	
Header value	'01	hex
Channel bandwidth	50	kHz
Unfaded C/N_0	43.0	dBHz
Burst duration	90	slots
Burst duration	2 400	ms
Ramp down	0.3	ms
Guard time	8.0	ms
Channel rate	33.6	kchip/s
Spreading factor	8	
Spreading code	SS0	Table 29
Modulation	BPSK	
Channel bits/symbol	1	
FEC rate	0.50	
FEC type	3GPP	Annex 1
Information rate/user	2.10	kbits/s
Number of simultaneous users	8	
E_b/N_0	9.8	dB
Channel Rice factor (*C/M*)	10	dB
Channel fading bandwidth	3	Hz
Target frame error rate	1	%
Pilot and data duration of burst	2 371	ms
Pilot duration	237.1	ms
Data duration	2 133.9	ms
Number of info bits	4 480	bits
Number of coded bits	8 960	bits
Block interleaver width	128	bits
Block interleaver height	70	bits
Interleaver size	8 960	bits
Number of info bytes	560	bytes

2.7.2 PL-Frame format 2

The PL-Frame format 2 is provided in Table A4-13.

TABLE A4-13

PL-Frame format 2

Downlink format	2	
Function	Reliable one way transmission	
Usage	Multicast, announcements, ack	
Header value	'02	hex
Channel bandwidth	50	kHz
Unfaded C/N_0	43.0	dBHz
Burst duration	90	slots
Burst duration	2 400	ms
Ramp down	0.3	ms
Guard time	8.0	ms
Channel rate	19.2	kchip/s
Spreading factor	1	
Modulation	QPSK	
Channel bits/symbol	2	
FEC rate	0.25	
FEC type	3GPP	Annex 1
Information rate/user	9.60	kbits/s
Number of simultaneous users	1	
E_b/N_0	3.2	dB
Channel Rice factor (C/M)	10	dB
Channel fading bandwidth	3	Hz
Target frame error rate	1	%
Pilot and data duration of burst	2 371	ms
Pilot duration	237.1	ms
Data duration	2 133.9	ms
Number of info bits	20 480	bits
Number of coded bits	81 920	bits
Block interleaver width	256	bits
Block interleaver height	320	bits
Interleaver size	81 920	bits
Number of info bytes	2 560	bytes

2.7.3 PL-Frame format 3

The PL-Frame format 3 is provided in Table A4-14.

TABLE A4-14

PL-Frame format 3

Downlink format	3	
Function	High throughput TDM channel	
Usage	File segment transfer	
Header value	'03	hex
Channel bandwidth	50	kHz
Unfaded C/N_0	50.0	dBHz
Burst duration	90	slots
Burst duration	2 400	ms
Ramp down	0.3	ms
Guard time	8.0	ms
Channel rate	19.2	kchip/s
Spreading factor	1	
Modulation	8PSK	
Channel bits/symbol	3	
FEC rate	0.50	
FEC Type	3GPP	Annex 1
Information rate/user	28.80	kbits/s
Number of simultaneous users	1	
E_b/N_0	5.4	dB
Channel Rice factor (C/M)	10	dB
Channel fading bandwidth	3	Hz
Target frame error rate	1	%
Pilot and data duration of burst	2 371	ms
Pilot duration	237.1	ms
Data duration	2 133.9	ms
Number of info bits	61 448	bits
Number of coded bits	122 896	bits
Block interleaver width	512	bits
Block interleaver height	241	bits
Interleaver size	123 392	bits
Number of info bytes	7 681	bytes

3 VDE-SAT link layer

3.1 Data encapsulation

The data segments of each PL-Frame contain multiple variable length encapsulated datagrams. Each datagram contains the following encapsulation fields:

– Datagram type (1 byte)

– Datagram size (3 bytes)

– Ship ID (4 bytes)

– Transaction ID (4 bytes, optional)

- Datagram sequence number (2 bytes, for multisegment datagrams)
- Source ID (8 bytes, optional)
- Datagram payload (variable)
- Data padding (variable, less than 8 bits)
- CRC (4 bytes).

3.2 Cyclic redundancy check

Refer to Annex 1.

3.3 Automatic repeat request (ARQ)

Datagrams may or may not use ARQ, this is defined for each datagram type. An ARQ will request selective retransmission of a specific lost datagram segment.

3.4 Acknowledgement (ACK)

All datagrams without CRC errors are acknowledged over the satellite link.

3.5 End delivery notification (EDN)

All datagrams successfully delivered to the destination will be notified to the source.

3.6 End delivery failure (EDF)

All datagrams not successfully delivered within the timeout or retry limit will be notified to the source.

3.7 Physical and logical channels

VDE-SAT protocols use several channels to carry data. These channels are separated into physical and logical channels. Every satellite transmits a Bulletin Board that defines the configuration of these channels.

3.7.1 Physical channels

The physical channels (PC) are determined by the centre frequency and bandwidth.

3.7.2 Logical channels

The logical channels (LC) are divided into signalling and data channels as described below.

3.8 Signalling logical channels

The following downlink signalling channels are used:

- Bulletin board signalling channel (BBSC)
- Announcement signalling channel (ASC)
- Multicast data channel (MDC)
- Unicast data channel (UDC).

3.8.1 Bulletin board signalling channel

The bulletin board defines the network configuration parameters such as signalling channels (control channels) and data channel(s), protocol versions and future network configuration.

~~A logical channel is defined by function, centre frequency, PL-Frame format and start of the first slot. The logical channels are normally repeated every frame, unless a network configuration change has taken place to optimise capacity.~~

~~Satellite parameters and network ID are also provided. Information about other satellites and networks may be provided. The Bulletin Board information does not change often, and for a small LEO satellite it is sufficient that the Bulletin Board is received once per pass, a repeat rate of once per minute is sufficient for most passes.~~

~~The BBSC uses PL-Frame format 1 defined in Table A4-12 and should be transmitted once every minute in the VDE satellite downlink exclusive channels (channel 2046 and 2086), starting at slot 0, the duration is 2.4 s (corresponding to 90 slots). A code division multiple access scheme is used to allow multiple satellites with overlapping coverage to transmit the Bulletin Board at the same time. The ship receiver should be able to receive bulletin boards from up to 8 satellites at the same time.~~

~~The full bulletin board messages may be transmitted over several frames. Essential information of the bulletin board will be repeated over every frame (every 60 s).~~

~~Bulletin Board content is shown in Table A4-15. All packets start with an 8 bit packet type, followed by an 8 bit field giving the length in bytes. Padding bits are used if the frame is not filled. The 4 last bytes are the 32 bit CRC applied to the whole PL-Frame.~~

~~TABLE A4-15~~

~~**Bulletin board construction**~~

~~Name~~	~~Description~~	~~Total size (bytes)~~	~~Repeat interval (frames)~~	~~Comment~~
~~Network ID~~	~~Network name, up to 16 ASCII characters~~	~~18~~	~~1~~	
~~Satellite ID~~	~~The ID of this satellite in a network. Up to 256 satellites per network.~~	~~3~~	~~1~~	
~~Bulletin board version~~	~~Version number of this Bulletin Board.~~ ~~Up to 256 frames active~~	~~3~~	~~1~~	

TABLE A4-15 (*end*)

Name	Description	Total size (bytes)	Repeat interval (frames)	Comment
Validity of this version	Lifetime of this version in number of 1 minute frames. 16 bits used.	4	1	
Future satellite status change	Packet providing information about planned future status change. From Julian day of year start, frame no, today and frame, new status.	13	1	
Back-up bulletin board frequency	Channel number above 156 MHz, 25 kHz resolution	3	1	
Satellite protocol capability	Index showing which protocols are supported by this satellite	3	1	
Downlink announcement/signalling channel configuration	Packet providing centre frequency, start slot, PL-Frame format no, logical channel number	6	1	8 bits are used for slots corresponding to actual slot number/10. A frame may contain multiple announcement channels to reduce protocol latency
Downlink data channel configuration	Packet providing centre frequency, start slot , PL-Frame format no, logical channel number	6	1	A frame may contain multiple data channels
Uplink random access/signalling channel configuration	Packet providing centre frequency, start slot , PL-Frame format no, logical channel number	6	1	A frame may contain multiple uplink signalling channels to reduce protocol latency
Uplink demand assign channel configuration	Packet providing centre frequency, start slot , PL-Frame format no, logical channel number	6	1	A frame may contain multiple data channels
This satellite ephemeris	Packet containing the ephemeris, validity	25	Flexible	GPS almanac format may be used.
Other satellite ephemeris	Packet containing network ID, satellite ID, status , ephemeris, validity	46	Flexible	GPS almanac format may be used.
Free text message	Containing up to 128 ASCII characters	9	Flexible	Network operator message to all ships, information only

The BBSC supports a classification of messages into logical categories of message types in the BBSC.

Different class of BBSC messages belong to one of the following categories:

1) Satellite system static configuration/status:

The Satellite system static configuration and status includes parameters such as satellite number, assigned number in constellation (for satellite constellations), ephemeris data in stated format, firmware version, etc.

2) Satellite system dynamic configuration information

a) BBSC management information:

The satellite system dynamic configuration pertaining to usage of the BBSC, which includes information for the BBSC itself, for example if time division duplexed, slot and or time information for next message packet to be transmitted (similar to role of COMSTATE in AIS), physical channel allocation for next transmission (if channel is being changed, or the physical channel must change to permit self or inter-system channel resource sharing).

b) Configuration of other physical and logical channels:

– Other dynamic configuration parameters for all other channels, including announcement signalling channel (ASC), multicast data channel (MDC), unicast data channel (UDC).

Note that assignments of the second category may change frequently, for example changing in the timeframe of a satellite pass (10-15 minutes).

For efficiency, and ease of processing information on BBSC, all message types have a configuration revision level, CRL, (or other numerical sequence number) that indicates relative freshness of the information, so that terrestrial receivers will be able to determine if there has been a change in the currently transmission, if so, the transceiver shall receive the entire data transmission, and make any required updates to dynamic parameters, such as logical channel definitions. If the configuration revision level is changed, however the remaining data packets are not received error free, the transceiver will cease any VDES transmission activities until updated dynamic configuration information is received error free.

In the event that the configuration revision level is unchanged from the state previously received, the receiver does not need to listen to the remainder of the BBSC transmission.

3.8.1.1 Note on configuration revision level parameter

A configuration revision level (CRL) should be very early in any single or multiple slot BBSC transmission. It is possible to also have more than one CRL in a long transmission, for example a CRL at the beginning of a BBSC transmission, reflecting the change level for all messages with the BBSC. Each of the categories of messages can also employ a CRL, reflecting their level of update.

In practice, every time any message is updated, its CRL is incremented, and if any message within a BBSC CRL is incremented, the top level CRL is also incremented.

The latter scheme allows a quick global view of changes, and then a lower level of granularity by message type as to changes. Such a scheme has benefits in low SNR and fading channels, allowing for reception of only partial messages, with the benefit of achieving high confidence knowledge of a change in the configuration.

3.8.2 Announcement signalling channel (ASC)

This channel will normally carry announcements, MAC information, up/downlink resource allocation, ARQs, ACKs and EDNs.

The channel is received by a large number of ships and a high margin PL-Frame format is used.

To reduce protocol latency the ASC may be repeated several times (different content) during a frame. Announcements include unicast and multicast (broadcast) datagrams.

The ASC uses PL-Frame format 1 or 2. The format the start slots are defined in the Bulletin Board.

The MAC information includes network version, congestion control (randomization interval, hold-off and minimum priority level).

The uplink resource allocation provides uplink data channel information to an individual ship following a resource request, the satellite makes a $C/(N_0+I_0)$ estimate which is used to select the highest throughput format with adequate link margin.

Table A4-16 to Table A4-20 provides several templates of ASC for different usage.

TABLE A4-16

Media access control (start of ASC)

Field name	Size (bytes)	Comment	Additional info
Packet type	1	Defines packet content. This packet is addressed to all ships, sub address 0.	
Packet size	1	Total size of this packet	The size may be implicit in most packet types, but some packet types may be of variable length.
Frame number	2	1 440 frames in 24 h	
Network version	1	Version defined on the Bulletin Board. Old versions are stored and retrieved as required.	
Satellite network status	1	Defines health of satellite, busy, reduced capacity, high latency	
Uplink access priority level	1	Ship messages have different levels of priority, distress is highest. Only messages with priority level equal to and higher than this number are accepted	
Retry interval	1	Wait time in slots before random access timeouts. Resolution is 10 slots	
Maximum message size	1	During congestion long messages may not be allowed. This field is an index to maximum discrete file sizes	

TABLE A4-17

Multicast announcement

Field name	Size (bytes)	Comment	Additional info
Packet type	1	Defines packet content. This packet is addressed to all ships, sub address 0.	Other multicast packets may address an area, class of terminals or types of ships
Packet size	1	Total size of this packet	The size may be implicit in most packet types, but some packet types may be of variable length.
Logical channel	1	Logical channels are defined in the BB, including centre frequency, start slot, number of slots and MODCOD	
Transaction ID	2	The satellite assigns a transaction ID for all uplink and downlink messages. This ID is used in ACKs, ARQ and End Delivery Notifications. Some messages may be repeated and this ID enables the terminal to discard already received messages.	

TABLE A4-18

Downlink assigned message announcement

Field name	Size (bytes)	Comment	Additional info
Packet type	1	Defines packet content	
Packet size	1	Total size of this packet	The size may be implicit in most packet types, but some packet types may be of variable length.
Ship ID	4	Physical MAC address of ship	
Ship sub address	2	Ship Gateway and M2M device IDs	
Logical channel	1	Logical channels are defined in the BB, including centre frequency, start slot, number of slots and MODCOD	
Transaction ID	2	The satellite assigns a transaction ID for all uplink and downlink messages. This ID is used in ACKs, ARQs, End Delivery Notifications. Some messages may be repeated and this ID enables the terminal to discard duplicate messages.	

TABLE A4-19

Uplink resource assignment

Field name	Size (bytes)	Comment	Additional info
Packet type	1	Defines packet content	
Packet size	1	Total size of this packet	The size may be implicit in most packet types, but some packet types may be of variable length.
Ship ID	4	Physical MAC address of ship	
Ship sub address	2	Ship gateway and M2M device ID	
Logical channel	1	Logical channels are defined in the BB, including centre frequency, start slot, number of slots and MODCOD	
Start slot	1	Start slot where ship starts transmission. Resolution 10 slots	
Transaction ID	2	The satellite assigns a transaction ID for all uplink and downlink messages. This ID is used in ACKs, ARQ and End Delivery Notifications. Some messages may be repeated and this ID enables the terminal to discard duplicate messages.	

TABLE A4-20

Uplink ACK

Field name	Size (bytes)	Comment	Additional info
Packet type	1	Defines packet content.	
Packet size	1	Total size of this packet	The size may be implicit in most packet types, but some packet types may be of variable length.
Ship ID	4	Physical MAC address of ship	
Ship sub address	2	Ship gateway and M2M device ID	
Logical channel	1	Used to point to a specific ship message. Transactions IDs are assigned by the satellite.	Enables ship to associate message with Transaction ID, used to determine if end delivery notification is received.
Receive slot	1	Slot where message was received also used to point to a specific message.	
Start slot	1	Start slot where ship starts transmission. Resolution 10 slots	
Transaction ID	2	The satellite assigns a transaction ID for all uplink and downlink messages. This ID is used in ACKs, End Delivery Notifications. Some messages may be repeated and this ID enables the terminal to discard duplicate messages.	

3.8.3 Multicast data channel (MDC)

This downlink channel is received by a large number of ships and a high margin PL-Frame format is used.

3.8.4 Unicast data channel (UDC)

This downlink channel is allocated a specific ship for the duration of a unicast datagram. This channel is set up after a ship responds to an announcement, and the response includes received signal quality information allowing the satellite to maximise throughput.

4 Network layer

4.1 Downlink data transfer protocols

The following downlink protocols shall be supported:

– Bulletin board transmission (network configuration).

– Multicast (one-way) (icemaps, weather info, notices to mariners)

– Unicast (shore to ship file transfer, up to 100 kBytes).

The protocols are shown in Fig. A4-10 – Fig. A4-13.

~~FIGURE A4-10~~

~~**Bulletin board with network version change**~~

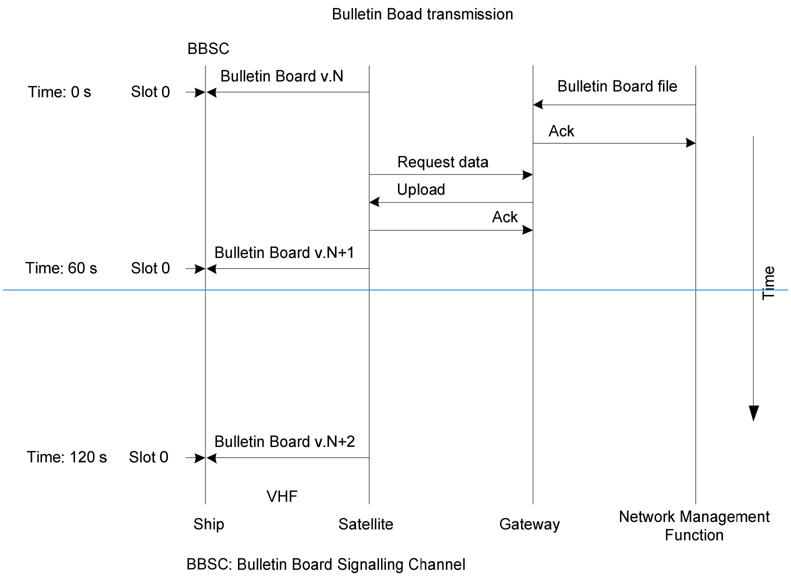
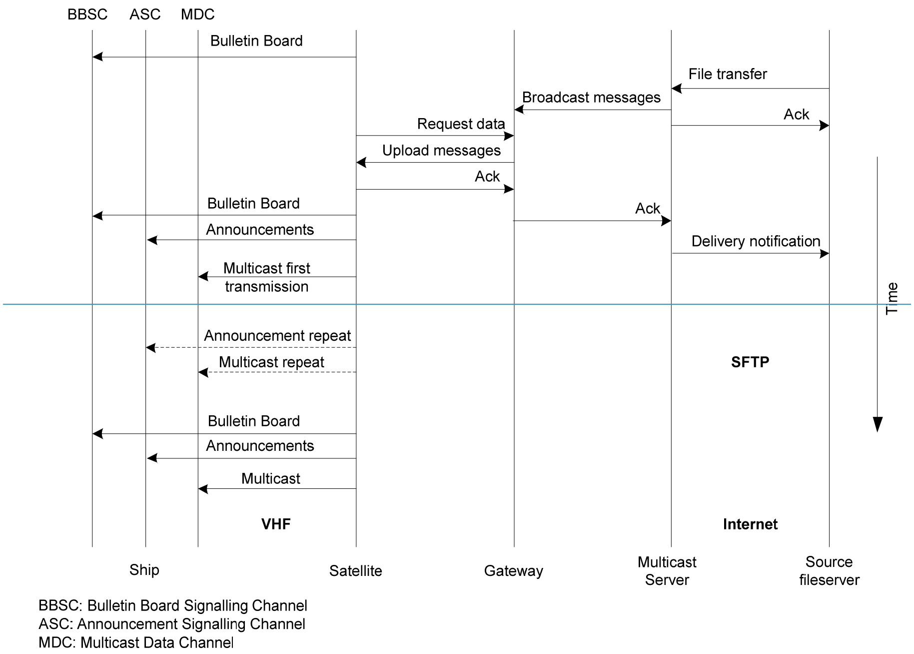


FIGURE A4-11

Multicast protocol (one-way)

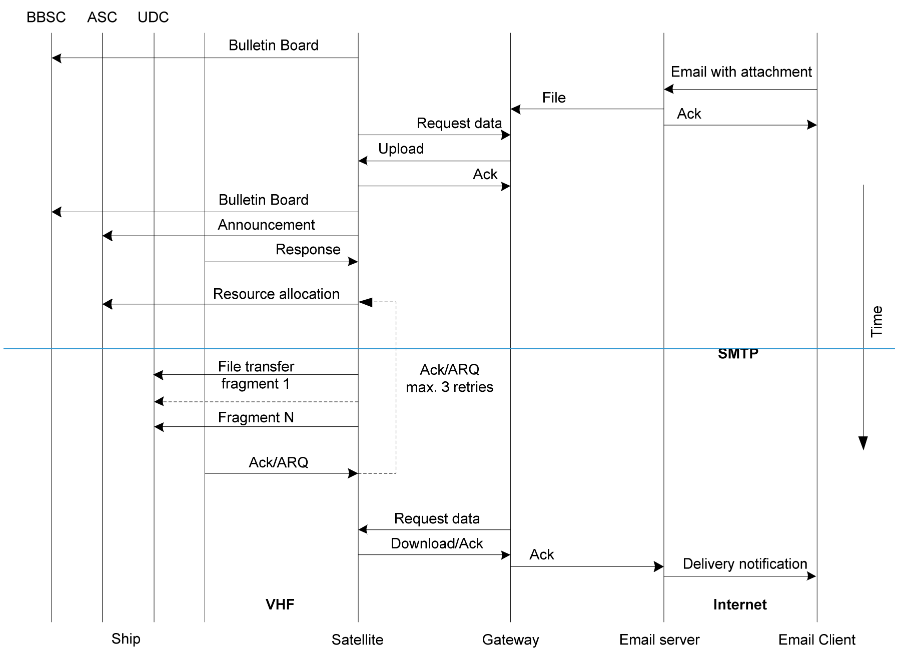
Multicast protocol (one way)



~~FIGURE A4-12~~

~~**Shore originated unicast (file transfer) protocol**~~

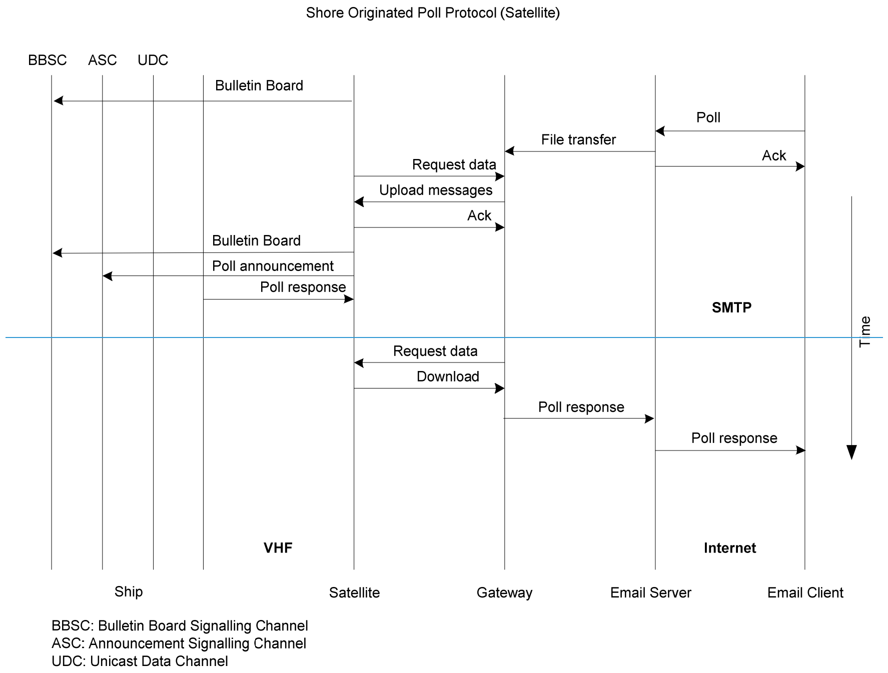
Shore originated unicast protocol



BBSC: Bulletin Board SignallingCchannel
ASC: Announcement Signalling Channel
UDC: Unicast Data Channel

FIGURE A4-13

Shore originated poll protocol



5 Transport layer

5.1 End to end protocols

Existing Internet protocols such as UDP, SNMP, secure file transfer protocol (SFTP), simple mail transfer protocol (SMTP) as shown in Figs. A4-10 to A4-13 are used.

Terrestrial IP protocols are assumed to be terminated at the satellite gateway.

5.2 Ship, gateway and device physical addressing

Most commercial ships use a 7-digit IMO number of which the last is a checksum, thus the IMO system can address 1 million ships. The 4 byte VDES physical addressing field has 4.3×10^9 unique IDs.

The number of networked devices on ships is growing fast and there is a need to directly address local gateways and devices.

In addition to the 4 byte address field, a 2 byte sub addressing field has been added.

The ship, local gateway and device addressing are shown in Table A4-21. Unlike MMSI, there will be no dedicated field or segmentation in this addressing scheme.

TABLE A4-21

Ship, Gateway and Device addressing

Addressing field	Usage	Range
32 bit physical address (all messages)	Ship Terminal ID	4.3 Billion
16 bit sub addressing	To address local gateways and transducers	Flexible, e.g. 16 gateways each with 4 096 transducers

5.3 Shore addressing of ships, gateways and devices

VDES will be accessed from shore using Internet, and it is desirable to use standard protocols such as email.

A database at the gateway will allow shore users to define their own meaningful ship, gateway and device names.

Annex 5

Technical characteristics of VDE satellite uplink in the VHF maritime mobile band

1 Introduction

This annex describes the characteristics of the VDE satellite uplink. In this context, the following types of functionality are envisaged:

– Two-way communications:
  – Shore initiated polling of information from ships;
  – Ship initiated enquiry for information from shore;
  – Ship initiated data transfer to shore.
– Transmit Only:
  – Collection of information from transmit-only VDES terminals. This could be either event driven or periodic. The time slot and frequency band for this service should be assigned by the bulletin board and announcement signalling channels.

In this annex low earth orbit (LEO) satellites with 600 km altitude are considered to present typical examples of VDE satellite solutions. It should be noted that other orbital selections are also possible according to the overall system design consideration.

The focus of this annex is to describe the physical layer and link layer of the OSI model as defined in Annex 1. The overall description of the network and the transport layers is provided in Annex 4.

2 VDE-SAT uplink physical layer

2.1 VDE-SAT uplink key parameters

This section outlines assumptions regarding the VDE-SAT uplink system parameters that are used as representative examples in this annex.

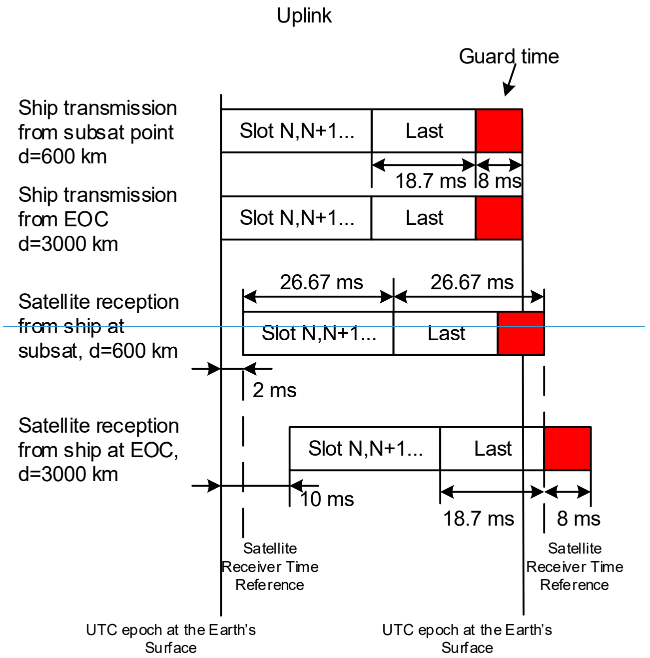
2.1.1 Satellite to surface distance range

The orbit height determines the satellite range variations. For example, for a 600 km LEO the maximum range is 2 830 km. For timing purposes a maximum range of 3 000 km will be used.

The minimum range is equal to the orbit height. For a LEO satellite at 600 km altitude the minimum range will be 600 km. This value is used to determine the minimum propagation delay time. Considering these exemplary values for the minimum and maximum ranges, the path delay will vary from 2 ms to 10 ms, a variation of 8 ms as shown in Fig. A5-1.

FIGURE A5-1

VDE-SAT Uplink timing



2.1.2 Transmitter requirements for mobile station

Refer to Annex 1.

2.1.3 Mobile station transmit antenna gain

Refer to Annex 1.

2.1.4 Link budget analysis

The link C/N_0 is determined by the satellite e.i.r.p., path losses, propagation losses, receiver sensitivity/figure of merit and local interference levels.

2.1.5 Ship e.i.r.p. vs. elevation angle

Refer to Annex 1.

2.1.6 Satellite antenna gain

Table A5-1 presents the gain of a 3-element Yagi satellite antenna with a peak gain of 8 dBi as a functon of elevation angle.

TABLE A5-1

Satellite antenna gain vs. ship elevation angle

Ship elevation angle	Nadir offset angle	Boresight offset angle	Satellite antenna gain
deg.	deg.	deg.	dBi
0	66.1	0	8
10	64.2	1.9	8
20	59.2	6.9	8
30	52.3	13.8	7.8
40	44.4	21.7	6.9
50	36	30.1	5.5
60	27.2	38.9	3.6
70	18.2	47.9	0.7
80	9.1	57	−2.2
90	0	66.1	−5.5

2.1.7 Satellite system noise temperature

The satellite noise level at the receiver input is shown in Table A5-2. Without external interference the system noise temperature is 25.7 dBK.

TABLE A5-2

Satellite receiver system noise temperature

Antenna noise temperature	200.0	K
Feed losses	1.0	dB
LNA noise figure	2.0	dB
LNA noise temperature	159.7	K
Feedloss noise temp. at LNA	56.1	K
Antenna noise temp. at LNA	158.9	K
System noise temp. at LNA	374.7	K
System noise temp. at LNA	25.7	dBK

2.1.8 Uplink C/N_0

The baseline uplink link budget is given in Table A5-3. It is optimised for 0 degree ship elevation angles.

It can be seen from Table A5-3 that the C/N_0 is better than 74 dBHz for ship elevation angles between 0 and 65 degrees.

TABLE A5-3

VDE-SAT Uplink link budget, 6 W ship transmit power

Ship elevation angle	Ship antenna gain	Ship e.i.r.p.	Polarization loss	Range	Path loss	Satellite antenna gain	Satellite G/T	C/N_0
deg	dBi	dBW	dB	km	dB	dBi	dB/K	dBHz
0	3	10.8	3	2 830	145.56	8	−17.6	73.2
10	3	10.8	3	1 932	142.25	8	−17.6	76.5
20	2.5	10.3	3	1 392	139.40	8	−17.6	78.9
30	1	8.8	3	1 075	137.16	7.8	−17.8	79.4
40	0	7.8	3	882	135.44	6.9	−18.7	79.2
50	−1.5	6.3	3	761	134.16	5.5	−20.1	77.6
60	−3	4.8	3	683	133.22	3.6	−22	75.2
70	−4	3.8	3	635	132.58	0.7	−24.9	71.9
80	−10	−2.2	3	608	132.21	−2.2	−27.8	63.4
90	−20	−12.2	3	600	132.09	−5.5	−31.1	50.2

2.1.9 Propagation effects

See § 2.1.10 of Annex 4.

2.2 Physical layer modulation schemes

VDE-SAT uplink supports different modulation to maximise spectral efficiency and throughput. The supported modulation methods are given in Table A5-4.

TABLE A5-4

Uplink modulation methods

Index	Bits/symbol	Data Modulation type	Bit mapping	Maximum Adjacent Channel Interference level with worst case Doppler
1	2	Gray encoded QPSK and OQPSK	Figure A5-2	Refer to Annex 1
2	3	Gray encoded 8PSK	Figure A5-3	
3	4	16APSK	Figure A5-4	
4	2	Spread Spectrum with Constant Envelope	See §Section 2.2.1	

FIGURE A5-2

QPSK symbol to bit mapping

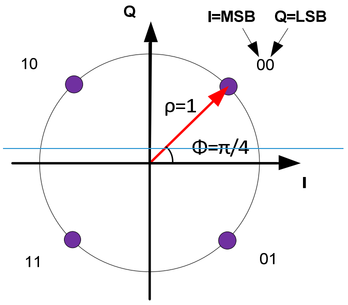


FIGURE A5-3

8PSK symbol to bit mapping

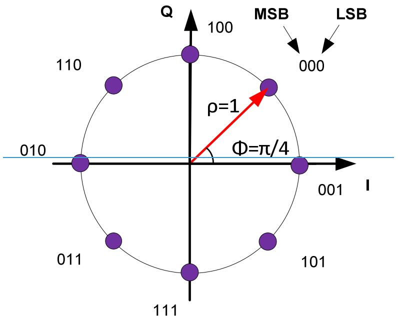
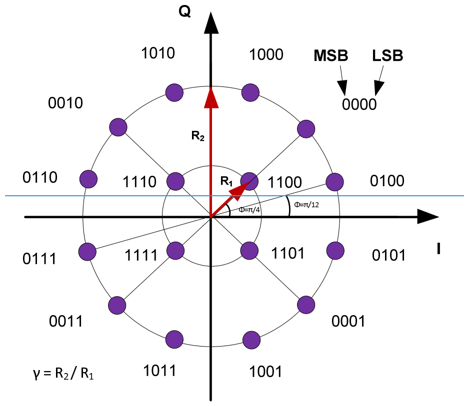


FIGURE A5-4

16APSK bit to symbol mapping



The 16 APSK modulation constellation is composed of two concentric rings of uniformly spaced 4 and 12 PSK points, respectively in the inner ring of radius R_1 and outer ring of radius R_2.

The ratio of the outer circle radius to the inner circle radius ($\gamma = R_2/R_1$) shall be equal to 3. R_1 shall be set to $1/\sqrt{7}$, R_2 shall be set to $3/\sqrt{7}$ in order to have the average signal energy equal to 1.

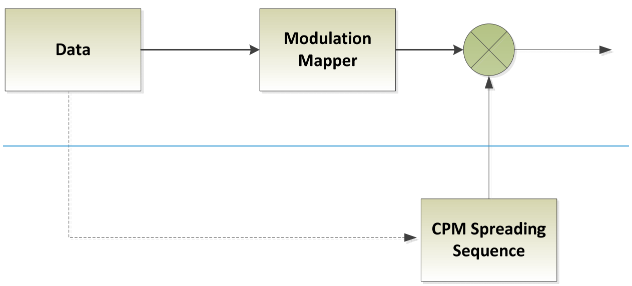
Similar to AIS, when data is output on the VHF data link it should be grouped in bytes of 8 bits from top to bottom of the table associated with each message in accordance with ISO/IEC 13239:2002. Each byte should be output with least significant bit first.

2.2.1 Spread spectrum with constant envelope

Direct sequence spreading with constant envelope can be implemented according to the spreading strategy {RD-3}. This provides a way to generate constant envelope signals whilst allowing the use of linear modulations (i.e. BPSK, or QPSK for data modulation). In this approach the CPM spreading sequences are selected such that the spread symbols maintain quasi continuous phase even at the transition from one symbol to the next. The CPM spreading principle is provided in Fig. A5-5.

FIGURE A5-5

CPM Spreading Principle



In order to avoid phase discontinuity at the data symbol transitions, the proposed solution is to adapt the spreading sequence to the modulation data. In other words, the CPM spreading sequence at the edge of each symbol is adapted according to the new input modulation symbol value to avoid any phase discontinuity. Such a solution produces a small loss at the receiver as the receiver does not know the edge symbol part of the used CPM spreading sequence. For a spreading factor of 16 or higher, the resulting correlation loss experienced by the receiver due to this issue is less than 0.25 dB. Performance losses with respect to conventional spreading is thus quite negligible provided that SF = 16 or larger is used.

The CPM spreading sequences are computed and optimized off line and then stored in the memory of the terminals and receivers. A single spreading code is sufficient for all the users in the system. There is thus no need for storing multiple spreading sequences but just a single spreading sequence.

The stored spreading sequence is then applied starting from the preamble and continuing in the data part (as shown in Fig. A5-6). It should be noted that the actual spreading sequence is actually partly dependent on the modulation symbols in order to ensure continuity of the signal phase when the modulation symbol changes (Fig. A5-5). The spread samples are computed on the basis of the current modulation symbol and previous modulation symbol. For QPSK modulation there are 4 possible values for the phase difference of these two symbols. An index from 0 to 3 can point to the possible phase differences and is used to address which of 4 possible spreading sequences is actually used for computing the output signal. Figure A5-7 illustrates the power spectral properties of the proposed modulation scheme (with spreading factor 16). Due to its constant envelope properties, this modulation scheme can operate with a transmit power amplifier operating close to saturation while maintaining a low power leakage to adjacent channels.

FIGURE A5-6

Proposed Spreading in the CPM

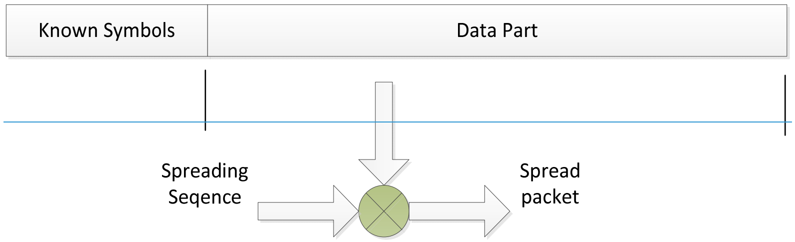
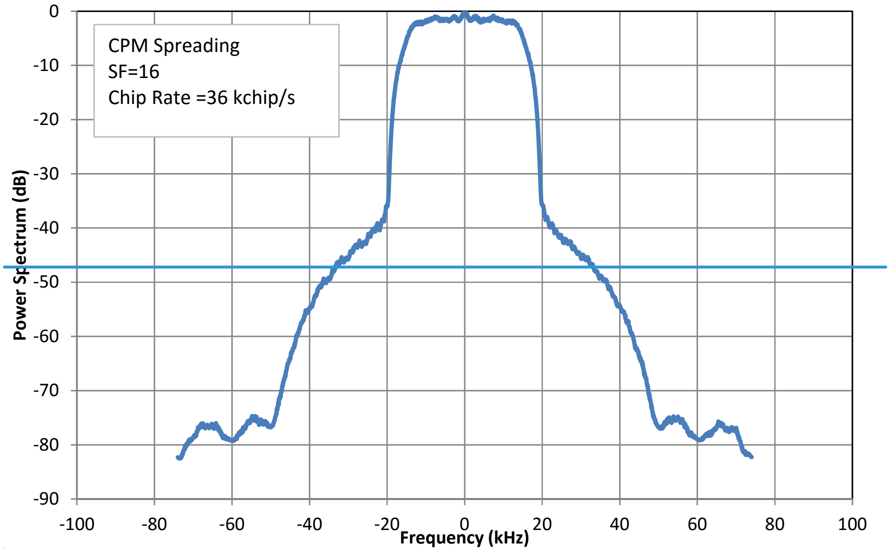


FIGURE A5-7

Power spectral properties of spread spectrum with constant envelope



2.3 Baseband shaping and quadrature modulation

The baseband symbols shall be squared root raised cosine filtered. The roll-off factor should be $\alpha = 0.25$ or $\alpha = 0.20$. It should be noted that the shaping is not applicable to CPM spreading.

2.4 Transmission timing accuracy

2.4.1 Symbol timing accuracy (at the output of satellite)

The timing accuracy of the transmit signal at the satellite should be better than 20 ppm.

2.4.2 Transmitter timing jitter

The timing jitter should be better than 5% of the symbol interval (peak value).

2.4.3 Slot transmission accuracy at the satellite output

The slot transmission accuracy should be better than 100 µs (peak) relative for example to GNSS reference timing.

2.5 Half duplex and full duplex satellites

See § 2.5 of Annex 4.

2.6 Frame hierarchy

The VDES frame structure is identical and synchronized in time on the Earth's surface to UTC (as in AIS). The frame hierarchy is shown in Annex 6.

2.6.1 Uplink physical layer frame (PL-Frame)

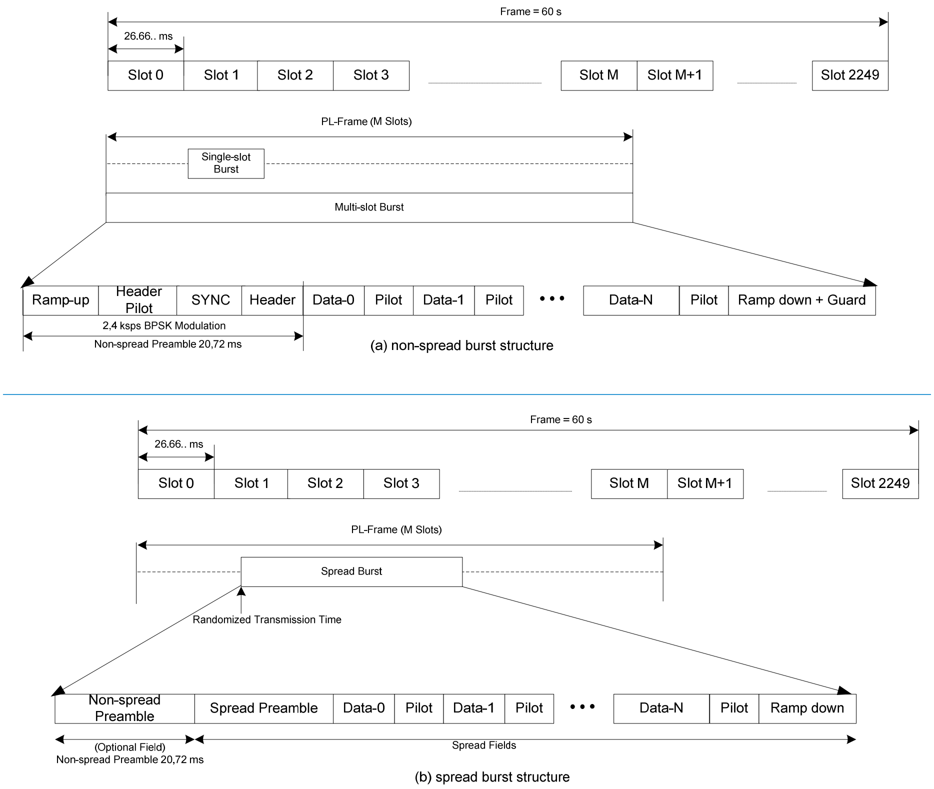
The uplink physical layer frame (PL-Frame) refers to a time window that the satellite expects to receive the VDE-SAT uplink signal. The PL-frame size is defined according to the PL-frame formats used for the VDE-SAT uplink. The current selected PL-frame intervals are 800 ms and 2.4 s.

2.6.2 Burst structure

For the VDE-SAT uplink, the active portion of PL-frame is referred to as a burst. Figure A5-8 illustrates the burst structure for non-spread and spread waveforms

FIGURE A5-8

VDE-SAT uplink burst structure (a) without spreading (b) with spreading



2.6.3 Guard time and ramp up

The ramp up time from −30 dBc to −1.5 dBc of the power shall occur in less than or equal to 300 µs for 50 kHz channel occupancy. This is a means to maintain compliancy with the adjacent channel interference requirements.

The guard time at the beginning of a burst may not be required, but has been provided to allow for future expansion of the pilot, synchronization word and the PL-Frame format header.

2.6.4 Preamble

For general information on the preamble, see Annex 1, § 3.3

A fixed format preamble as shown in Fig. A5-8 is used for non-spread burst and optionally for spread bursts. It consists of a CW (unmodulated carrier) pilot, a unique synchronization word and a format header. The preamble duration is shown in Table A5-5.

TABLE A5-5

Preamble Duration

Parameter	Value	Unit
Ramp up	0.30	ms
Symbol rate	2.4	ksym/s
Modulation	BPSK	
CW pilot duration	4	symbols
CW pilot duration	1.67	ms
(SYNC) UW size	13	bits
(SYNC) UW duration	5.42	ms
Header size	32	bits
Header duration	13.33	ms

2.6.5 Synchronization pilot

Pilot symbols (one or several) are inserted periodically among the data symbols. The number of known symbols per pilot field and the distance (in symbols) between two consecutive pilot fields are defined on case by case basis (per each PL-Frame format).

2.6.6 Synchronization (SYNC) unique word

For general information on the synchronization word, see Annex 1, § 3.3

The PL-Frame synchronization word and header format is fixed for all transmissions. (It is defined as part of non-spread preamble and considered optional field for spread burst as shown in Fig. A5-8). The 13 bit Barker code unique word, as defined in Annex 4 (Table A4-10) is modulated with BPSK at a symbol rate of 2.4 ksym/s.

2.6.7 PL-Frame header

For general information on frame structure, see Annex 1, § 3.3

The header is BPSK modulated and spread the same way as the synchronization word described above. This PL-Frame header defines the following parameter associated with the each PL-Frame:

- PL-Frame duration (as an integer multiple of a slot duration)
- Burst duration
- Number of data slots (M) per PL-Frame
- Symbol rate
- Modulation type
- FEC type
- FEC rate
- Interleaver type
- Scrambler type
- Spreading Factor (1 or higher)
- Spreading sequence (1 or as defined).

The header provides 7 bits to define up to 128 PL-Frame formats. The PL-Frame header is encoded to 32 bits. It is modulated with BPSK at a symbol rate of 2.4 ksym/s. Refer to Annex 4 for more details.

2.6.8 Direct sequence spreading

The VDE-SAT spread bursts are shown in Fig. A5-8 (b). The spread burst may contain optionally a non-spread field similar to that of a non-spread burst. This optional filed would contain known symbols, SYNC and PL-frame header all modulated as BPSK and at a symbol rate of 2.4 ksym/s.

A spread burst should carry a spread preamble allowing the detection of the burst as very low $C/(N_0+I_0)$ conditions. The data filed and pilot fields are spread as well.

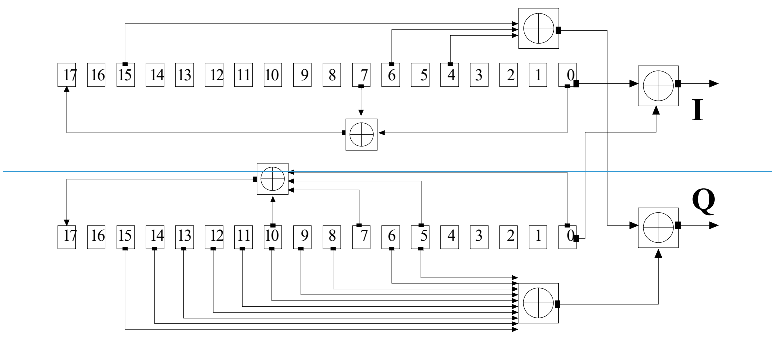
Each pilot filed contains one or several known QPSK symbols. The pilot field distances are defined per PL-Frame format.

The transmission time of a spread burst is randomly selected within the PL-Frame duration (keeping margin so that the full burst fits within the PL-Frame interval). The actual PL-frame size and the burst size are defined per PL-Frame format.

For the VDE-SAT uplink, the spreading codes should be selected from long Pseudo Noise (PN) Sequence. A spreading strategy similar to the one used in the down link of the 3GPP standard is adopted recommended for VDE-SAT uplink. The complex spreading code is shown in Fig. A5-9 i.e. obtained through a long Gold code which is used to generate the I and Q scrambling sequences (with the Q sequence obtained by a different phase of the same Gold code).

FIGURE A5-9

Complex Scrambling code generation



2.6.9 Data segment forward error correction coding

The FEC coding scheme applied to the data segment of PL-Frames is similar to the FEC code of the 3GPP standard. The definition of the FEC is Annex 1 since a common FEC scheme is applicable to VDE-SAT and VDE terrestrial.

2.6.10 Data segments

As shown in the frame hierarchy, each PL-Frame includes one or several data segments. Data segments contain channel symbols that carry encoded information bits. In each PL-Frame, the encoded bits are mapped into segment of N of interleaved data.

2.6.11 Physical layer scrambling

Prior to modulation (and spreading if applicable), each PL-Frame samples, excluding the SYNC word, should be randomized for energy dispersal by multiplying the (I + jQ) samples by a complex randomization sequence ($C_I + jC_Q$):

$I_{SCRAMBLED} = (I\ C_I - Q\ C_Q)$

$Q_{SCRAMBLED} = (I\ C_Q + Q\ C_I)$.

The randomization sequence rate corresponds to the PL-Frame symbol rate, thus it has no impact on the occupied signal bandwidth. The randomization sequence shall be reinitialized at the end of each burst. The randomization sequence length should be truncated to the length of the burst (excluding the SYNC word).

The scrambling code sequence should be pre-defined according to the PL-Frame format.

2.6.12 Channel interleaver

A block channel interleaver is considered on the VDE-SAT in order to reduce the impact of the channel short blockage (for example due to the AIS transmission from the vessel or fast fading events). The channel interleaver is applied to the code words at the output of the encoder.

The interleaver is a block interleaver composed by N_r rows and N_c columns. The interleaver memory in this case (from the point of view of the transmitter) is written by row and read by columns after having applied an inter-column permutation. The proposed column permutation is resulting from reading the column index in the reverse order (bit shuffling), i.e. the column with index $i_5, i_4, i_3, i_2, i_1, i_0$ become the column $i_0, i_1, i_2, i_3, i_4, i_5$, where i_0, i_1, i_2, i_3, i_4 and i_5 are the bits representing a given number.

In more general cases (where the number of columns is not an integer power of 2), the interleaver index can be made available as table lookup.

2.6.13 Ramp down

For general information on the ramp down, see Annex 1, § 3.3

The ramp down occurs at the end of each burst (as shown in Fig. A5-8) followed by the guard time. The overall duration of the ramp-down and guard time is 8.88 ms while the ramp-down time from 90% to 10% of the power should occur in less than 300 µs.

2.6.14 Guard time

The guard time is added to the end of each PL-Frame. The guard time duration is 8.88 ms. This time is adequate to cover the differential delay between the shortest and the longest propagation time within the coverage area of a LEO satellite at 600 km altitude (or lower).

2.7 VDE-SAT uplink PL-Frame formats

This section defines several PL-Frame formats that are used for signalling and data transmission on the VDE-SAT uplink channels. All formats consist of a fixed preamble and a data portion as shown in Fig. A5-8. The data portion is defined in the tables below. The pilot duration is one symbol after every 9 data symbols.

2.7.1 VDE-SAT Uplink PL-Frame format 1

The VDE-Sat uplink PL-Frame format 1 is provided in Table A5-6.

In the uplink PL-Frame format 2, the optional non-spread preamble field is used. Each pilot field consists of 1 symbol only. The distance between two consecutive pilot symbols is 9 data symbols.

There are 24 pilot symbols in total in each burst. The spread preamble filed contains 14 known symbols.

TABLE A5-6

VDE-Sat uplink PL-Frame Format 1

Uplink format	1	
Function	Direct Sequence Spread random access	
Usage	Request, response, ACK and short message	
Header value	'41	hex
Channel bandwidth	50	kHz
Slots available for RA	30	slots
Unfaded C/N_0	73.0	dBHz
Burst duration	5	slots
Burst duration	133.33	ms
Ramp down	0.30	ms
Guard time	8.0	ms
Channel rate	19.2	kchip/s
Spreading factor	8	
Modulation	QPSK	
Channel bits/symbol	2	
FEC rate	1/3	
Information rate/user	1.60	kbits/s
Eb/N0	41.0	dB
Channel Rice factor (*C/M*)	10	dB
Channel fading bandwidth	3	Hz
Target frame error rate	1.00	%
Pilot duration	9	ms
(spread) Preamble duration	5.83	ms
Data duration	90	ms
Number of information bits	144	bits
Block interleaver width	16	bits
Block interleaver height	27	bits
Number of info bytes	18	bytes
Packet type field	1	bytes
Ship ID field	4	bytes
Destination short address	2	bytes

TABLE A5-6 (*end*)

Repeat transmission offset field	2	bytes
Received C/N_0 field	1	bytes
Packet sequence number	0	bytes
Transaction ID	0	bytes
CRC	4	bytes
Payload	4	bytes

2.7.2 VDE-SAT uplink PL-Frame format 2

The VDE-SAT uplink PL-Frame format 2 is provided in Table A5-7.

In the uplink PL-Frame format 2, the optional non-spread preamble field is not used. Each pilot field consists of 1 symbol only. The distance between two consecutive pilot symbols is 9 data symbols. There are 24 pilot symbols in total in each burst. The spread preamble filed contains 64 known symbols.

TABLE A5-7

VDE-SAT uplink PL-Frame format 2

Uplink format	2	
Function	Direct Sequence Spread random access with constant envelope	
Usage	Request, response, ACK and short message	
Header value	'42	hex
Channel bandwidth	50	kHz
Slots available for RA	30	slots
Unfaded C/N_0	73.0	dBHz
Burst duration	5	slots
Burst duration	133.33	ms
Ramp down	0.30	ms
Guard time	6.36	ms
Chip rate	38.4	kchip/s
Spreading factor	16	
Modulation	CPM/QPSK	
Channel bits/symbol	2	
FEC rate	1/3	
Information rate/user	1.60	kbits/s
E_b/N_0	41.0	dB
Channel Rice factor (C/M)	10	dB
Channel fading bandwidth	3	Hz
Target frame error rate	< 1.00	%
(spread) Preamble symbols	64	symbols

TABLE A5-7 (*end*)

(spread) Preamble duration	26.67	ms
Preamble, Pilot and data duration of burst	126.67	ms
Pilot duration	10	ms
Data duration	90	ms
Number of information bits	144	bits
Block interleaver width	16	bits
Block interleaver height	27	bits
Number of info bytes	18	bytes
Packet type field	1	bytes
Ship ID field	4	bytes
Destination short address	2	bytes
Repeat transmission offset field	2	bytes
Received C/N_0 field	1	bytes
Packet sequence number	0	bytes
Transaction ID	0	bytes
CRC	4	bytes
Payload	4	bytes

2.7.3 VDE-SAT uplink PL-Frame format 3

The VDE-SAT uplink PL-Frame format 3 is provided in Table A5-8.

TABLE A5-8

VDE-SAT uplink PL-Frame format 3

Uplink format	3	
Function	TDMA (non-spread) random access, high margin	
Usage	Request, response, ACK and short message	
Header value	'43	hex
Channel bandwidth	50	kHz
Slots available for RA	30	slots
Unfaded C/N_0	73.0	dBHz
Burst duration	1	slots
Burst duration	26.67	ms
Ramp down	0.30	ms
Guard time	0.0	ms
Channel rate	33.6	kchip/s
Spreading factor	1	
Modulation	OQPSK	

TABLE A5-8 (*end*)

Channel bits/symbol	2	
FEC rate	3/4	
Information rate/user	50.40	kbits/s
Number of simultaneous users	1	
E_b/N_0	26.0	dB
Channel rice factor (*C/M*)	10	dB
Channel fading bandwidth	3	Hz
Target frame error rate	1.00	%
Pilot and data duration of burst	5.65	ms
Pilot duration	0.57	ms
Data duration	5.09	ms
Number of information bits	256	bits
Block interleaver width	24	bits
Block interleaver height	15	bits
Number of info bytes	32	bytes
Packet type field	1	bytes
Ship ID field	4	bytes
Destination short address	2	bytes
Repeat transmission offset field	2	bytes
Received C/N_0 field	1	bytes
Packet sequence number	0	bytes
Transaction ID	0	bytes
CRC	4	bytes
Payload	18	bytes

2.7.4 VDE-SAT uplink PL-Frame format 4

The VDE-SAT uplink PL-Frame format 4 is provided in Table A5-9.

TABLE A5-9

VDE-SAT uplink PL-Frame Format 4

Uplink format	4	
Function	TDMA (non-spread) random access, high throughput	
Usage	Request, response, ACK and short message	
Header value	'44	hex
Channel bandwidth	50	kHz
Slots available for RA	30	slots
Unfaded C/N_0	73.0	dBHz
Burst duration	1	slots
Burst duration	26.67	ms
Ramp down	0.30	ms
Guard time	0.0	ms
Channel rate	33.6	kchip/s
Spreading factor	1	
Modulation	16APSK	
Channel bits/symbol	4	
FEC rate	3/4	
Information rate/user	100.80	kbits/s
Number of simultaneous users	1	
E_b/N_0	23.0	dB
Channel Rice factor (C/M)	10	dB
Channel fading bandwidth	3	Hz
Target frame error rate	1.00	%
Pilot and data duration of burst	5.65	ms
Pilot duration	0.57	ms
Data duration	5.09	ms
Number of information bits	512	bits
Block interleaver width	32	bits
Block interleaver height	22	bits
Number of info bytes	64	bytes
Packet type field	1	bytes
Ship ID field	4	bytes
Destination short address	2	bytes
Repeat transmission offset field	2	bytes
Received C/N_0 field	1	bytes
Packet sequence number	0	bytes
Transaction ID	0	bytes
CRC	4	bytes
Payload	50	bytes

2.7.5 VDE-SAT uplink PL-Frame format 5

The VDE-SAT uplink PL-Frame format 5 is provided in Table A5-10.

TABLE A5-10

VDE-SAT uplink PL-Frame format 5

Uplink format	5	
Function	TDM (non-spread) demand assign	
Usage	Long packet file fragments	
Header value	'45	hex
Channel bandwidth	50	kHz
Slots available for RA	Not applicable	s
Unfaded C/N_0	73.0	dBHz
Burst duration	30	slots
Burst duration	800	ms
Ramp down	0.30	ms
Guard time	8.0	ms
Channel rate	33.6	kchip/s
Spreading factor	1	
Modulation	16APSK	
Channel bits/symbol	4	
FEC rate	3/4	
Information rate/user	100.80	kbits/s
Number of simultaneous users	1	
E_b/N_0	23.0	dB
Channel Rice factor (C/M)	10	dB
Channel fading bandwidth	3	Hz
Target frame error rate	1.00	%
Pilot and data duration of burst	770.98	ms
Pilot duration	77.10	ms
Data duration	693.89	ms
Number of information bits	69 936	bits
Block interleaver width	360	bits
Block interleaver height	260	bits
Number of info bytes	8 742	bytes
Packet type field	1	bytes
Ship ID field	4	bytes
Destination short adress	0	bytes
Repeat transmission offset field	0	bytes
Received C/N_0 field	1	bytes
Packet sequence number	0	bytes
Transaction ID	4	bytes
CRC	4	bytes
Payload	8 728	bytes

3 VDE-SAT link layer

3.1 Data encapsulation

The data segments of each PL-Frame contain multiple variable length encapsulated datagrams. Each datagram contains the following encapsulation fields:

– Datagram type (1 byte)

– Datagram size (3 bytes)

– Destination (variable, up to 254 bytes, optional)

– Transaction ID (4 bytes, optional)

– Datagram sequence number (2 bytes, for multi segment datagrams)

– Source ID (6 bytes, optional)

– Datagram payload (variable)

– Data padding (variable, less than 8 bits)

– CRC (4 bytes).

3.2 Cyclic redundancy check

Refer to Annex 1.

3.3 Automatic repeat request (ARQ)

Datagrams may or may not use ARQ, this is defined for each datagram type. An ARQ will request selective retransmission of a specific lost datagram segment.

3.4 Acknowledgement (ACK)

All datagrams without CRC errors are acknowledged over the satellite link.

3.5 End delivery notification (EDN)

All datagrams successfully delivered to the destination will be notified to the source.

3.6 End delivery failure (EDF)

All datagrams not successfully delivered within the timeout or retry limit will be notified to the source.

3.7 Physical and logical channels

VDE-SAT protocols use several channels to carry data. These channels are separated into physical and logical channels. Every satellite transmits a bulletin board that defines the configuration of these channels.

3.8 Physical channels

The Physical channels (PC) are determined by the centre frequency and bandwidth.

3.8.1 Logical channels

The logical channels (LC) are divided into signalling and data channels as described below.

3.9 Signalling logical channels

The following uplink signalling channels are used:

– Random access resource request

– Announcement response

– Acknowledgement

– Automatic repeat request.

3.9.1 Random access resource request (RQSC)

A ship uses this channel to access the network. A ship will randomly select the transmission time within the slots allocated for this channel on the Bulletin Board. The downlink Announcement Channel provides congestion control parameters such as retry interval and message priority.

The request includes a downlink C/N_0 estimate and message size.

3.9.2 Announcement response channel (ARSC)

A ship uses this channel to inform the satellite that it is ready to receive a message. The response includes a downlink C/N_0 estimate.

3.9.3 Acknowledgement (ACK)

A ship uses this channel to inform the satellite that it has received a message correctly (CRC match).

3.9.4 Automatic repeat request signalling channel (ARQSC)

A ship uses this channel to inform the satellite that it has not received a message correctly (CRC failure). The ship can request retransmission of the whole message or up to 4 fragments. The acknowledgement includes a downlink C/N_0 estimate.

3.10 Data logical channels

The following data channels are used:

– Random access short messages

– Assigned (dedicated) data transfer.

3.10.1 Random access short messaging channel (RADC)

This channel is used for short messages that fit in a single transmission. Terrestrial addressing may require up to 254 bytes, and every ship uses therefore a 2 byte look-up table at the coast earth station for address translation.

3.10.2 Assigned data transfer channel (ADDC)

This channel is assigned by the satellite following a resource request from a ship. It is intended for longer messages and is optimized to achieve a higher throughput.

4 Network layer

4.1 Uplink data transfer protocols

The following protocols shall be supported:

– Ship originated single packet data transfer

– Ship originated multi-packet data transfer.

~~The protocols are shown in Fig. A5-10 to Fig. A5-12.~~

~~FIGURE A5-10~~

~~**Ship originated single packet data transfer**~~

Ship originated Single Packet data Transfer

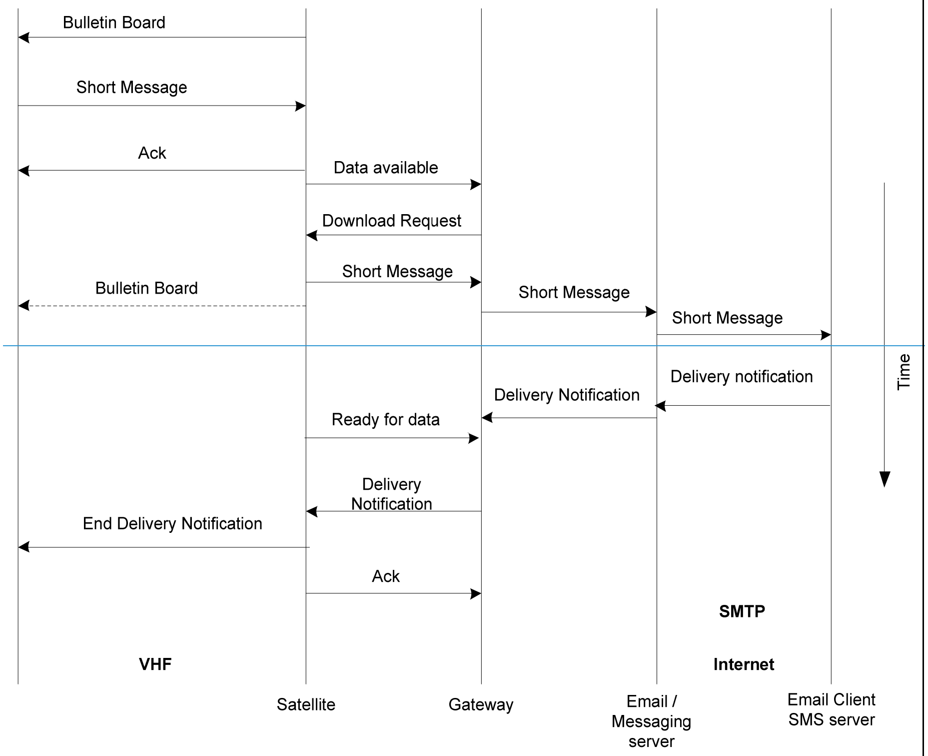
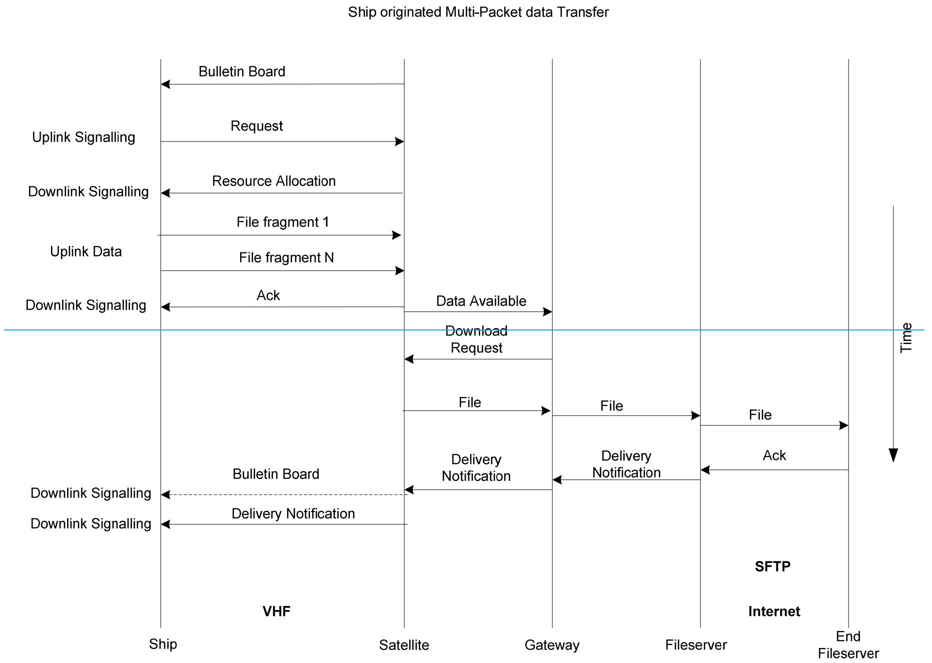


FIGURE A5-11

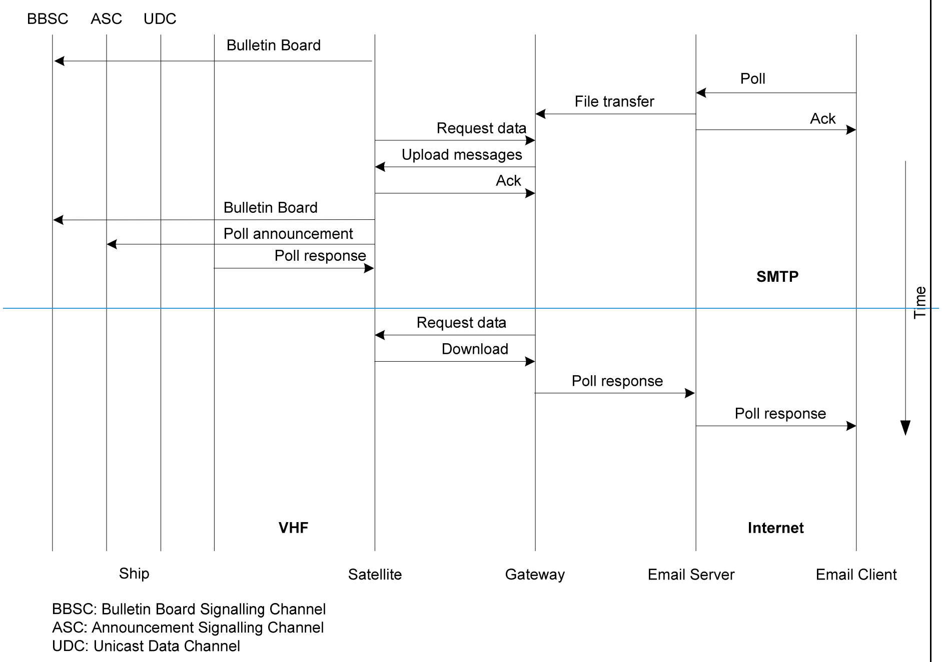
Ship originated multi-packet data transfer



~~FIGURE A5-12~~

~~**Shore oriented poll protocol**~~

Shore Originated Poll Protocol (Satellite)



~~5 Transport layer~~

~~Refer to Annex 4.~~

Annex 6

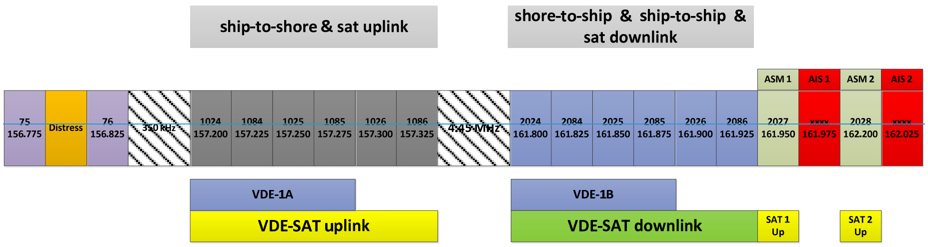
Resource sharing method for VDES Terrestrial and Satellite Services

1 Introduction

This Annex describes how resource sharing (i.e. in time and frequency) for utilizing the VHF spectrum available among different VDE terrestrial and satellite services should be accomplished. The baseline for VDES spectrum allocation is according to the frequency utilization plan illustrated in Fig. A6-1.

FIGURE A6-1

VDES spectrum allocation



where:

- Four channels 1024, 1084, 1025 and 1085 are shared between ship-to-shore and ship-to-satellite (VDE-SAT uplink) services
- Two channels 1026 and 1086 are exclusively reserved for ship-to-satellite communications
- Four channels 2024, 2084, 2025 and 2085 are shared among shore-to-ship, ship-to-ship and satellite-to-ship (VDE-SAT downlink) services
- Two channels 2026 and 2086 are exclusively reserved for satellite-to-ship communications services.

The VDE-SAT is an effective means to extend the VDES to areas outside of coastal VHF coverage. However, due to the large footprint of satellite, the VDE-SAT downlink signal may interfere with terrestrial VDE in the coastal areas when satellite is in visibility. Similarly, the terrestrial ship-to-shore VDE signals can interfere with the satellite reception of VDE-SAT uplink when a VDE Satellite is in the field of view.

The method described in this Annex for resource sharing is derived based on the characteristics of VDE terrestrial and VDE Satellite, particularly the use of bulletin board and announcement signalling channels, as defined in Annexes 3, 4 and 5.

2 VDES resource sharing principles

2.1 Common frequency-time frame structure

The transmission timing of all VDES components (i.e. AIS, ASM, VDE-SAT and VDE terrestrial), is defined based on a common frame structure that is synchronized in time on the Earth's surface to the UTC.

The duration of each frame is 60 seconds. Each frame consists of 2 250 slots.

All VDES transmitters should be synchronized to this common frame structure and use a common addressing of frame constituents (i.e. sub frames and slots), so that each slot can be uniquely identified per frame. Frame 0 starts at 00:00:00 UTC, and there are 1 440 distinct frames in a day. The impact of leap second should be accounted for to avoid any propagation of error.

The frame and slot boundaries should respected independent of the frequency band to a VDE service.

Uncertainties due to the propagation delay or Doppler effect should be compensated, or accounted for (e.g. see Annexes 3 and 4 for guard time definition and Annex 4 for guard bands)

2.2 AIS priority

Understanding that when transmissions occurs a VDES mobile station with a single antenna will suffer decreased receiver sensitivity, care must be taken to respect the AIS transmission and reception as the highest priority.

2.3 Coordination with ASM

Similar to all VDES components, ASM transmission respects a common frame structure.

For the ASM channels and for VDE ship to ship communications on VDE-1B band, transmissions are accomplished through the use of candidate slot selection as described in Annex 2, § 3.3.1.2.

2.4 Shore station VDES control area

The VDES resource assignments in the proximity of a shore station is monitored and controlled by a shore station. Shore stations utilize terrestrial bulletin board (TBB) and announcement signalling channels (ASC) to coordinate the resource assignment within the control area. The shore station may incorporate information regarding VDE satellite communications within the TBB and ASC. The shore station may acquire the VDE satellite information directly from the VDE Satellite downlink (the satellite bulletin board and ASC) or in coordination with the satellite service providers.

There are dedicated slots and frequency bands for TBB and ASC that are reserved to communicate the required information to each vessel in the control area of a shore station. The default (or initial) assignment are described in Section 4 of this Annex.

2.5 VDE-SAT resource assignment

Each satellite should use bulletin board and announcement channels (as defined in Annex 4) to communicate the VDE-SAT resource assignments (both downlink and uplink) to vessels in the coverage area.

There are dedicated slots and frequency bands for the satellite bulletin board and announcement channels that are reserved to communicate the required information to each vessel in the field of view of a satellite.

Since the satellite coverage may include several shore station control areas, the VDE-SAT resource assignment should respect all requirements of shore control areas that are within the field of view at any given time. Within each satellite orbit the information regarding the resource assignment should be updated according to the shore station control areas in the satellite field of view.

A default (or initial) VDE-SAT resource allocation is defined in § 4 below to serve as the starting point for the resource sharing.

3 Frame hierarchy definition

The frame hierarchy is shown in Fig. A7-2. The frame hierarchy definition is independent of the assigned bandwidth to the VDE channel

3.1 Time slot

The time slot is a time interval of approximately 26.667 ms (60 000 / 2 250 = 80/3 ≈ 26.667).

3.2 Hexslot

Six timeslots should form a Hexslot (HS). The HS has duration of 160 ms.

The HS should be numbered cyclically from 0 to 4. The HS should be incremented after every 6 time slots.

3.3 Timeslot numbering

The timeslots within a Hexslot should be numbered from 0 to 5 and a particular timeslot should be referenced by its timeslot number (TN).

3.4 Uberslot

Five Hexslots should form a Uberslot (US). The US should have duration of 800 ms.

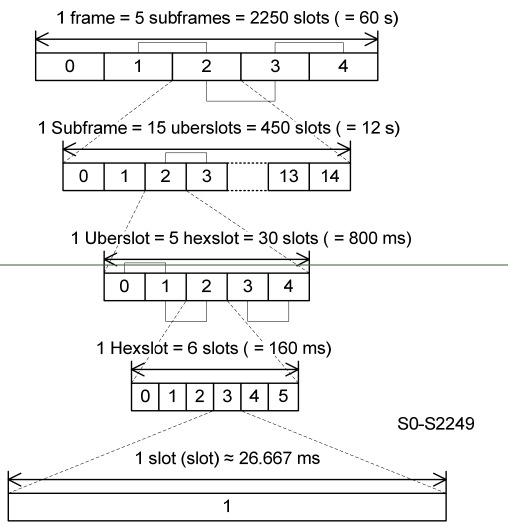
The US should be numbered by a US Number. The US should be cyclically numbered from 0 to 14. The US should be incremented whenever the Hexslot returns to 0.

3.5 Sub frame

Fifteen US should form a sub frame. The sub frame should have duration of 12 seconds. The sub frame should be numbered by a sub frame Number. The PL-Frame should be cyclically numbered from 0 to 4. The sub frame should be incremented whenever the US returns to 0.

FIGURE A6-2

Frame Hierarchy for shared frequency



43 Frame hierarchy definition

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3.1 Time slot

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3.4 Uberslot

Five Hexslots should form a Uberslot (US). The US should have duration of 800 ms.

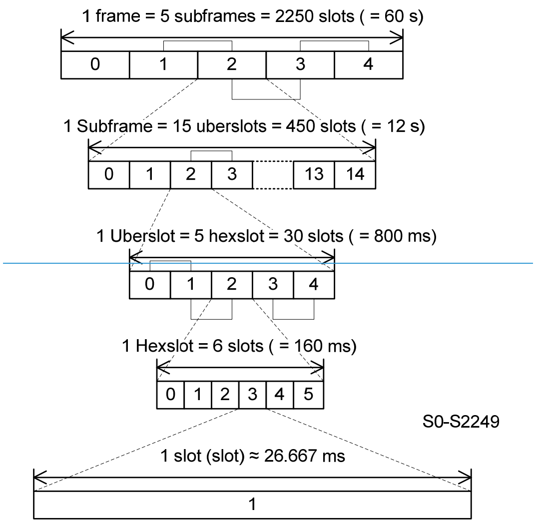
The US should be numbered by a US Number. The US should be cyclically numbered from 0 to 14. The US should be incremented whenever the Hexslot returns to 0.

3.5 Sub frame

Fifteen US should form a sub frame. The sub frame should have duration of 12 seconds. The sub frame should be numbered by a sub frame Number. The PL Frame should be cyclically numbered from 0 to 4. The sub frame should be incremented whenever the US returns to 0.

FIGURE A6-2

Frame Hierarchy for shared frequency



3 VDE terrestrial and VDE-SAT downlink resource sharing

Figure A6-3 2 illustrates the method of frequency and time slot coordination among VDE shore-to-ship, ship-to-ship and satellite downlink systems.

According to the frequency utilization plan, channels 2026 and 2086 are dedicated to VDE Satellite downlink. Within these exclusive VDE-SAT bands, there are dedicated time slots that are assigned to the satellite bulletin board and announcement signalling channels. Figure A6-3 2 shows the location of these slots in each frame. There are 90 consecutive slots (1/5th of sub frame duration) that are assigned to the signalling channels and the bulletin board in each sub frame (the assignment is repeated 5 times in each frame). Other slot assignments in the exclusive VDE-SAT frequency bands are managed based on the content of the bulletin board and announcement signalling channels.

The assignment may change dynamically (according to the satellite coverage or temporal demands).

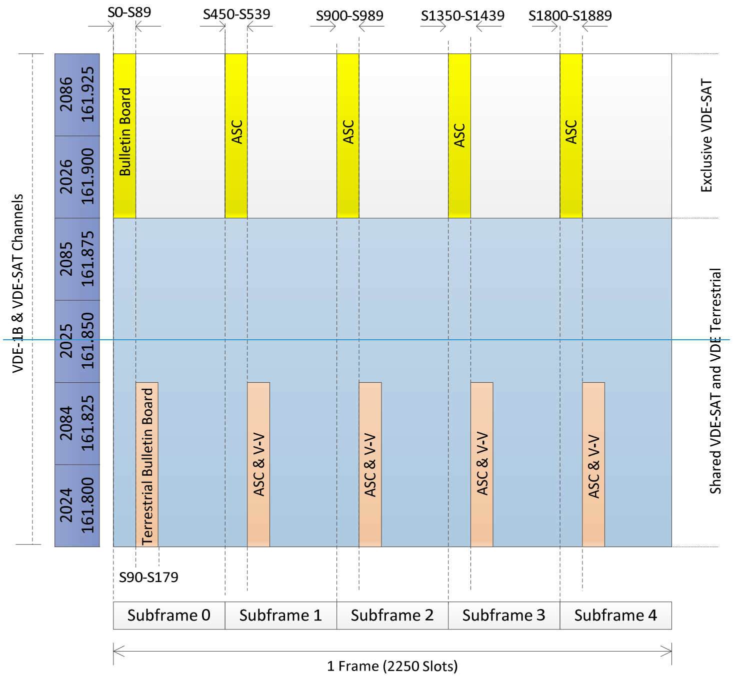
Channels 2024, 2084, 2025 and 2085 are shared between VDE-SAT Downlink and VDE terrestrial. Depending on the satellite coverage area and the shore control areas, the resource assignment may vary.

There are dedicated time slots in channel 2024 and 2084 that are assigned to the terrestrial signalling channel and terrestrial bulletin board, as shown in Fig. A6-32. These slots should not be used by VDE-SAT downlink. In each sub frame, 90 slots are assigned for the signalling. The same time slots are considered for ship-to-ship when ships are outside the control area of a shore VDE station.

A shore station may assign all the slots of VDE-1B for terrestrial services when there is no transmitting VDE satellite in the field of view.

FIGURE A6-32

Resource sharing between VDE-SAT downlink and VDE terrestrial



43.1 Initial resource sharing configuration

The resource sharing between VDE-SAT downlink and VDE shore-to-ship and ship-to-ship relies on the bulletin board and announcement channels of the satellite and shore stations. As an initial configuration for resource sharing, a static assignment in time and frequency should be adopted by the terrestrial and satellite entities. Figure A6-34 illustrates the initial configuration where:

– Channels 2024 and 2084 are exclusively used for terrestrial VDE, maintaining the original signalling assignment that was described above (as per Fig. A6-23).

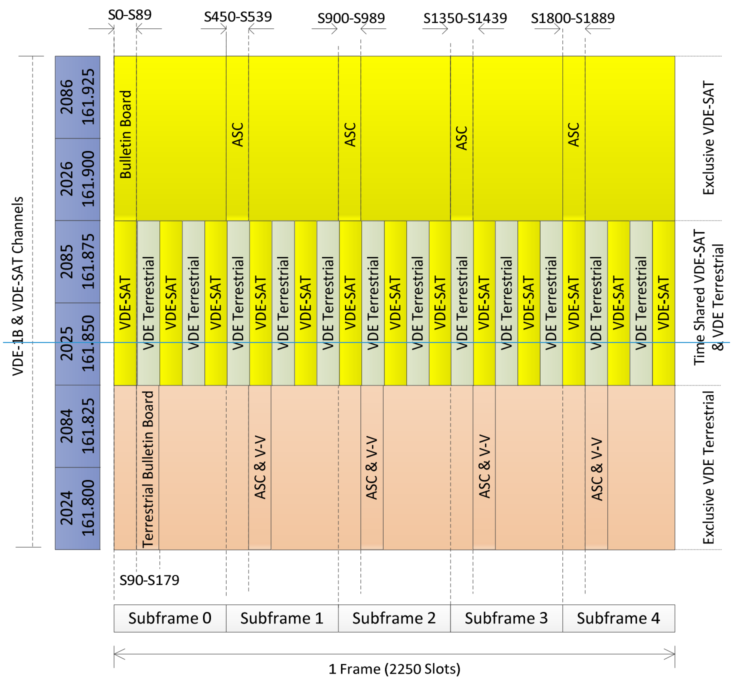
– Channels 2026 and 2086 are exclusively used for VDE-SAT downlink, maintaining the original signalling assignment that was described above (as per Fig.e A6-23).

– Channels 2025 and 2085 are time shared between VDE-SAT downlink and VDE terrestrial services. The time sharing is based on time intervals of 2.4 s (90 slots) that are assigned periodically to VDE-SAT and VDE terrestrial services (as shown in Fig. A6-34).

As the starting point of VDES resource sharing or in the absence of coordination between the shore and satellite operation, this resource sharing method should be used.

FIGURE A6-34

Initial resource sharing between VDE-SAT downlink and VDE terrestrial



54 Sharing between different VDE satellite systems

The sharing between two or more satellite system is organized by using the bulletin board, delivered by satellites in VDE-Sat downlink band (channels 2026 and 2086), as described in Annex 6.

The bulletin board provides as a minimum:

– Satellite and constellation ID
– Satellite ephemeris
– Downlink communication characteristics: spreading code (if any), time slots for broadcast, time slots for other communications, volume of data to downlink, and
– Uplink communication characteristics: spreading code (if any), available time slots for interrogation, available time slots for uplink, global communication channel load, etc.

By listening the bulletin board (transmitted every minute), ships can determine:

– When a satellite will be visible, and identify the satellite
– When a satellite will next be visible (based on ephemeris data)
– A satellite's transmission characteristics (Doppler and delay, based on ephemeris data)
– Which data a ship shall receive (the security-related and safety-related broadcast downlink) and when they will be transmitted, and
– When it may initiate a communication for uplink or downlink of data, and globally in which part of the frame this initiated communication will take place.

The physical channel used for the bulletin board should allow for detection of overlapping signals received from multiple satellites. The use of direct sequence spreading as defined in Annex 4 (PL-Frame format 1) allows for detection of up to 8 overlapping signals.

65 VDE-1A terrestrial and VDE-SAT uplink resource sharing

At the lower frequency bands, channel 1026 and 1086 are dedicated to VDE-SAT uplink while channels 1024, 1084, 1025 and 1085 are shared for terrestrial and satellite communications.

The exclusive VDE-SAT uplink channels may be used for dedicated (demand assigned) or random access to satellite. Since there is no VDE terrestrial interference on these two channels, these channels should be used for higher priority message (safety, distress, acknowledgement, etc.).

The coordination between the VDE terrestrial (ship-to-shore) and VDE-SAT uplink is achieved using the bulletin board signalling channel as defined on the VDE-SAT downlink.

The use of direct sequence spreading for VDE-SAT uplink channel may provide a higher level of resilience in the presence of VDE ship-to-shore interfering signals.

Annex 7

Original design considerations to validate the VDES concept

1 Introduction

This annex provides additional information on the technical considerations of the VDES. It identifies aspects of both terrestrial and satellite VDE components, including access scheme options, antenna design and system sharing.

The annex reflects all original materials that were used to develop Annexes 2 through 6.

2 Summary of operational capability and performance

This Annex demonstrates the following operational capability and performance:

- Protection of GMDSS and AIS, i.e. recognizing that the implementation of VDES must ensure that the function of digital selective calling, AIS and voice distress, safety and calling communication (channel 16), are not impaired
- Relief of AIS VDL congestion
- Raw ASM data transfer at 28.8 kbits/s
- Raw VDE data transfer ship-to-ship, ship-to-shore and shore-to-ship at 307.2 kbits/s
- Raw VDE satellite data transfer up to 240 kbits/s
- VDE satellite downlink that satisfies the PFD mask requirements
- VDE shore-to-ship and ship-to-shore service to 85 km (46 NM)
- Channel access and sharing schemes that organize the links and mitigate conflicts
- Full VDES satellite and terrestrial functionality from a single shipborne antenna.

3 Technical considerations for VHF data exchange system access schemes

This section provides technical considerations in designing access schemes for VDE terrestrial, VDE Satellite and the interaction between these VDES components.

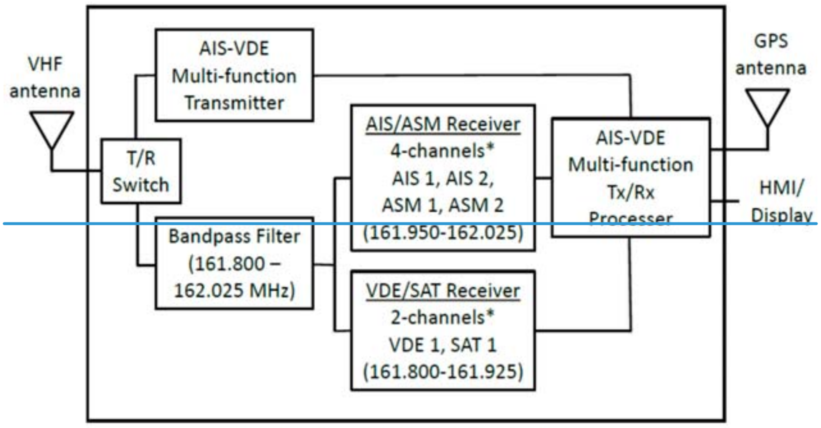
From Figure A1-1, the satellite downlink shares the spectrum with the terrestrial ship-to-ship and shore-to-ship links, and the satellite uplink shares the spectrum with the terrestrial ship-to-shore link. Thus, access schemes should be considered to mitigate potential conflicts between the links.

4 Time division multiple access scheme for the VHF date exchange terrestrial service

The VDES terrestrial service is comprised of ASM, VDE ship-to-shore, VDE shore-to-ship and VDE ship-to-ship. An example of a shipborne VDES transceiver implementation is illustrated in Figure. A7-1. Note that in this implementation example all receivers, including the AIS receivers, are protected from blocking from the shipborne VHF radio by the band-pass filter that attenuates signals from the lower side of RR Appendix **18** band. The AIS receiver blocking issue, along with the fact that the AIS can share the same antenna with the other VDES functions, is incentive for manufacturers to consider this implementation for their VDES system designs.

FIGURE A7-1

Example VHF data exchange system transceiver implementation



* For example, SDR (software defined radio) technology may be used.

4.1 Time division multiple access schemes

4.1.1 Time division multiple access scheme for the VHF data exchange system application specific message channels

Note that Recommendation ITU-R M.1371 specifies the access schemes for the AIS messages, including ITDMAATDMA, on the AIS channels. It also specifies the structure for ASM and the content options for these messages. VDES provides dedicated ASM channels to relieve congestion on the AIS channels. Under VDES, the access scheme for using the ASM channels could initially be Carrier-Sense TDMA (CSTDMA) for the first transmission in a frame, followed by ITDMAATDMA for subsequent transmissions in that frame. This scheme mitigates simultaneous transmissions by ships and/or shore stations on the ASM channels. An ASM transmission should not exceed five contiguous slots.

4.1.2 Time division multiple access scheme for the VHF data exchange system ship-to-shore link

The TDMA access scheme for the VDE1-A, ship-to-shore link, could be by reservation through ITDMAATDMA from an ASM on either one of the ASM channels, as described in § 4.1.1. A VDE1-A ship-to-shore transmission should not exceed five contiguous slots.

4.1.3 Time division multiple access scheme for the VHF data exchange system ship-to-ship link

The TDMA access scheme for the VDE1-B, ship-to-ship link, could be the same as for the ASM channels, i.e. initially by CSTDMA for the first transmission in a frame, followed by ITDMAATDMA for subsequent transmissions in that frame. This scheme mitigates simultaneous ship-to-ship transmissions. A VDE1-B ship-to-ship transmission should not exceed five contiguous slots.

4.1.4 Time division multiple access scheme for the VHF data exchange system shore-to-ship link

The TDMA access scheme for the VDE1-B, shore-to-ship link, could be the same as for the VDE1 ship-to-shore link, i.e. by reservation through ITDMAATDMA from an ASM on either one of the ASM channels. This is necessary because the shore station usually has a very wide coverage area compared to ships, and it needs to have priority access to the VDE1 channel in its coverage area. A VDE1-B shore-to-ship transmission should not exceed five contiguous slots.

4.2 Sharing options for the VHF data exchange terrestrial and VHF data exchange satellite services

4.2.1 VHF data exchange terrestrial links on the upper legs (VDE1-B) and VHF data exchange satellite downlink

Table A4-1 provides the PFD at the Earth's surface from the satellite downlink at various elevation angles from 0° to 90°. Although the PFD mask is selected to minimize interference to the land mobile service and to maximize reception by ship VDES stations, there is a potential effect of raising the noise floor for reception of the terrestrial VDES links during satellite VDE downlink transmissions when the satellite is the field of view.

Issues to be considered for the sharing the VDE1-B frequencies and the VDE-SAT Downlink are:

– When shipborne VDES transceivers are simplex they cannot receive while transmitting

– VDE-SAT downlink transmission levels, by raising the noise floor, will potentially have an impact on reception of ship-to-ship and shore-to-ship VDES

– Ship-to-ship and shore-to-ship VDES transmissions, depending on the distance, by co-channel interference, will potentially interfere with reception of the VDE-SAT downlink.

4.2.1.1 Frequency division multiple access

Frequency division multiple access (FDMA) is accomplished by using only the upper 50 kHz for the VDE-SAT downlink, i.e. the two channels 2026 and 2086. The FDMA would mitigate the last two issues stated above. Compared to other techniques proposed below, the FDMA would be the most straightforward to implement. However it would result in a reduction of the bandwidth to 1/3, and cause the VDE-SAT downlink transmissions to last three times longer for the same payload, and it would not mitigate the first issue stated above.

4.2.1.2 Time division multiple access

TDMA approach for shore-to-ship/ship-to-ship and VDE-SAT downlink services would allow the full use of the spectrum assigned to each service in a time sharing manner. Time sharing can mitigate all the three of the issues stated in § 4.2.1 above. However, it would impose some design challenges for the VDE-SAT components and compromise the throughput of the VDE-SAT downlink.

The AIS-based TDMA slot structure (2 250 slots/minute/frame) and access schemes (ITDMAATDMA, CSTDMA and FATDMA) that are used for VDES are defined in Recommendation ITU-R M.1371. This TDMA organization scheme protects the integrity of the AIS and is used to organize and synchronize the ASM and VDE transmissions.

4.2.1.3 Full frequency reuse (simultaneous transmission)

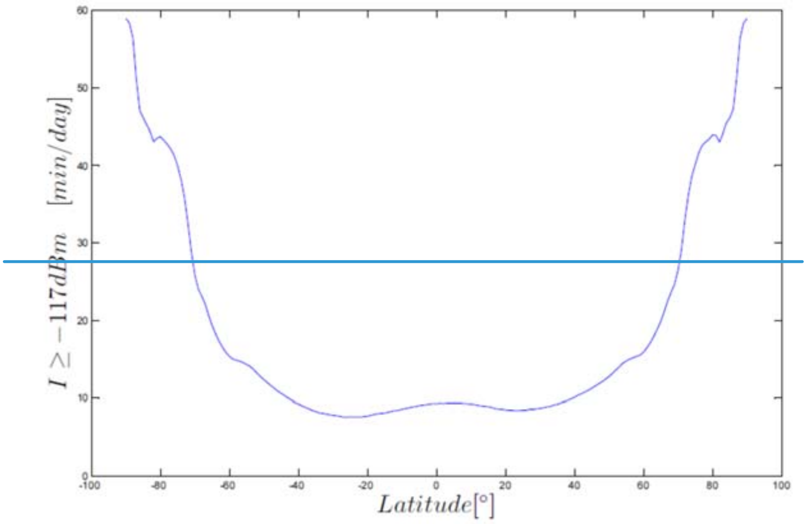
In this approach, the terrestrial and satellite components are allowed to simultaneously use channels 2024, 2084, 2025 and 2085. The VDE-SAT downlink will additionally use channels 2026 and 2086. The VDE-SAT downlink could continuously broadcast to maximize the data dissemination to a large number of ships in its field of view. This would allow for more efficient implementation of the VDE-

SAT receivers. The interference caused by the VDE-SAT downlink on the VDE terrestrial could, in principle, be compensated for by the use of more protected coding scheme in the terrestrial link, only during the satellite passage.

For a most likely scenario of Low Earth Orbit satellites with a polar orbit, the impact of satellite interference could be limited to only less than 15 minutes per day per satellite for geographical locations with latitudes within ±50 degrees, as shown in Figure. A7-2.

FIGURE A7-2

Time duration where signal level exceeds −117 dBm as a function of geographical position



4.2.2 VHF data exchange terrestrial (VDE1-A) and VHF data exchange satellite uplink

Due to the large field of view, a passing satellite would receive a number of colliding messages from different VDE-terrestrial links (ship-to-shore) simultaneously that would interfere with ship-to-satellite links (channels 1024, 1084, 1025 and 1085). The following multiple access schemes can be envisaged to mitigate/minimize the impact of VDE terrestrial link on VDE satellite uplink.

4.2.2.1 Frequency division multiple access

The frequency division multi-access scheme separates the satellite channels into two groups: Channels 1024, 1084, 1025 and 1085 that are subject to terrestrial interference are considered as a single or multi carrier satellite uplink channel(s). Highly robust waveforms would be selected for these channels to allow for interference mitigations caused by VDE terrestrial.

The second group of carriers are considered to occupy channels 1026 and 1086 where no VDE terrestrial transmission is present.

4.2.2.2 Time division multiple access

VDE-SAT uplink follows the same frame structure as VDE terrestrial occupying VDE1-A channels. There are pre-assigned time slotslots dedicated to satellite transmission preventing interference from any VDE terrestrial link.

Recommendation ITU-R M.1371 specifies the access schemes for the AIS Messages, including ITDMAATDMA, on the AIS channels, and it specifies the structure for ASM with various contents. VDES provides dedicated ASM channels to relieve congestion on the AIS channels. Under VDES, the access scheme for using the ASM channels could be initially by CSTDMA (Carrier-Sense TDMA) for the first transmission in a frame, followed by ITDMAATDMA for subsequent transmissions in that frame. This scheme mitigates simultaneous transmissions by ships and/or shore stations on the ASM channels.

Commenté [SP95]: This is wrong, we need another text here!

4.2.2.3 Full frequency reuse

The terrestrial and satellite components are allowed to simultaneously use channels 1024, 1084, 1025 and 1085. The VDE-SAT uplink would use properly designed waveforms occupying the VDE-SAT uplink channels to minimize the impact of interference caused by the VDE terrestrial transmissions.

5 VHF data exchange – terrestrial

5.1 Waveforms for VHF data exchange

5.1.1 Transmission waveforms for VHF data exchange terrestrial links

ITU-approved waveforms for spectrum-efficient data transmission in the VHF maritime band are described in Recommendation ITU-R M.1842. These waveforms have been demonstrated in the land-mobile service and in maritime trials, to provide robust data service and to mitigate multipath degradation at extended propagation ranges in intense electromagnetic environments. Table A7-1 below provides a comparison of performance between the current AIS standard, Recommendation ITU-R M.1371, and the new applications introduced for the terrestrial VDES links, ASM and VDE. Note that the spectrum efficiency for the AIS is much lower than for VDES, but the AIS modulation has superior co-channel rejection which provides better range discrimination and improved safety of navigation for ships. Each modulation type is intended to best fit its designated application (AIS, ASM and VDE).

Propagation range predictions for the terrestrial links are provided in Annex 3 in accordance with the ITU propagation standard Recommendation ITU-R P.1546-5.

TABLE A7-1

ITU-standard transmission waveforms for automatic identification system, application specific message and VHF data exchange terrestrial links

	25 kHz Channels for AIS	25 kHz Channels for ASM	100 kHz Channels for VDE
ITU standard	ITU-R M.1371	ITU-R M.1842-1 Annex 1	ITU-R M.1842-1 Annex 4***
Digital modulation	GMSK, single carrier	π/4 DQPSK, single carrier	16-QAM, 32 multi-carriers, 2.7 kHz spacing
Data rate (raw)*	9.6 kbits/s (1X)	28.8 kbits/s (3X)	307.2 kbits/s (32X)
Sensitivity**	−107 dBm (min) −112 dBm (typical)	−107 dBm (min) −112 dBm (typical)	−98 dBm (ships) −103 dBm (base stations)
Co-channel rejection (CCR)**	10 dB	19 dB	19 dB
AIS message types	1, 2, 3, 5, 18, 19, 27 ...	6, 7, 8, 12, 13, 14, 25, 26 and ASM	VDE messages
Rationale	Optimum choice (better CCR) for position reports in a ship-to-ship navigation safety environment.	Provides higher (3X) data transmission than AIS. Inferior CCR (+9 dB) and range discrimination compared to AIS.	Provides much higher (32X) data transmission than AIS. Inferior CCR (+9 dB) and range discrimination compared to AIS.

* These figures are raw, over the air, bit transmission rates. The data rates are less, subject to coding, packet structure and forward error correction (FEC).

** These figures are based on published standards. For AIS, the standard is IEC 61993-2 and for VDE the standard is ETSI EN 300 392-2 version 3.4.1, which refers to a land mobile application TETRA.

*** For greater robustness where needed, ITU-R M.1842-1 Annex 1 may be used.

5.1.2 Transmission waveform for the 25 kHz application specific message channels

Transmission of ASM on 25 kHz channels should be by π/4 DQPSK single carrier modulation as described in Annex 1 of Recommendation ITU-R M.1842-1. FEC is applied due to the fact that the ASM messages are not repeated as are AIS position reports (which do not have FEC). The waveform is recommended because it has high sensitivity, 70 dB adjacent channel power ratio (ACPR) and 28.8 kbits/s data rate.

– It is generated by phase modulation with an inter symbol rotation of π/4 radians. This produces an amplitude envelope with very moderate peak to average power ratio (PAPR);

– It has excellent characteristics for detection by satellites as required by the channel plan.

5.1.3 Transmission waveform for the 100 kHz VHF data exchange channels

Transmission of VDE on 100 kHz channels should be by 16-QAM, 32 multi-carriers, with 2.7 kHz spacing and 307.2 kbits/s data rate as described in Recommendation ITU-R M.1842-1 Annex 4. This multi-carrier scheme is not OFDM (orthogonal frequency division multiple access) since the carrier spacing is 2.7 kHz which provides more inter-carrier margin than OFDM which would require 2.4 kHz spacing. This waveform is comprised of 32 multi-carriers. Each carrier is modulated by 16-QAM to generate 4-bit symbols at 2 400 symbols/s (2 400 symbols/s/carrier × 4 bits/symbol = 9 600 bits/s/carrier).

The long symbol duration (2 400 symbols/s = 416.7 µs/symbol) is designed to mitigate multi-path inter-symbol interference, since (ref: Report ITU-R M.2317) reflections in a 100 kHz maritime channel environment have been found to be contained primarily within the first 10.4 µs. It is noted that further reflections were beyond this, some as far as 50 µs. By comparison, note that AIS uses

GMSK to generate 2-bit symbols at 4 800 symbols/s (9 600 bits/s) and that its excellent propagation characteristics have been proven in practice.

The modulation, coding and scrambling techniques described in EN 300 392-2 v.3.4.1 are combined to reduce the amplitude envelope PAPR (PAPR ≤ 10dB) to mitigate the RF power transmitter design difficulty. Both analogue, e.g. Doherty amplifier (DA), and digital, e.g. envelope tracking (ET) and digital pre-distortion (DPD), design techniques for RF power amplifiers are available to provide better than 50% efficiency with this waveform. By comparison, the AIS power amplifiers used by ships and base stations are also approximately 50% efficient. A technical report describing these techniques and others for modern high efficiency power amplifiers with actual test results can be found at: http://www.microwavejournal.com/articles/21965-modern-high-efficiency-amplifier-design-envelope-tracking-doherty-and-outphasing.

Note that the analogue design approach using Doherty amplifiers provides efficiency over 50% and the original patent for this technology has expired. Solid state Doherty amplifiers are currently in service in cellular terrestrial infrastructures which produce the range of power levels needed for shipborne VDES transceivers (12.5 W) and VDES base stations (50 W).

5.2 Antenna options for VHF data exchange system terrestrial stations

Commercially available antenna options for the VDES terrestrial stations are characterized in Figure A7-3 below. Since the shipborne antenna is required to receive the VDES satellite downlink at high elevation angles, the 0 dBd (2.1 dBi) option is selected. To achieve optimum satellite reception, this antenna should be mounted as high as possible, preferably on an extension pole, on the ship to minimize obstructions to the antenna's view of the horizon. For the terrestrial VDES base station, the 6 dBd (8 dBi) option is selected. These two antennas are used in the propagation range predictions in Annex 2.

Figure A7-4 presents a mask for the receiving antenna gain as a function of elevation that would allow the received signal from satellite to be at constant power level at the receiver input for a wide range of elevation angles, taking into account the PFD constraints imposed on the VDE-SAT downlink (ref. Table A4-1 of Annex 1). Although this mask may not represent the antenna pattern associated with a commercially available antenna, it could serve as a guide for designing an antenna to enhance the satellite reception. The same mask is also applicable to the design of shipborne antenna for VDE terrestrial link due its high directivity in the horizontal direction. Annex 3 provides further rationale for the selection of this mask.

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FIGURE A7-3

Antenna options for shipborne VHF data exchange system stations

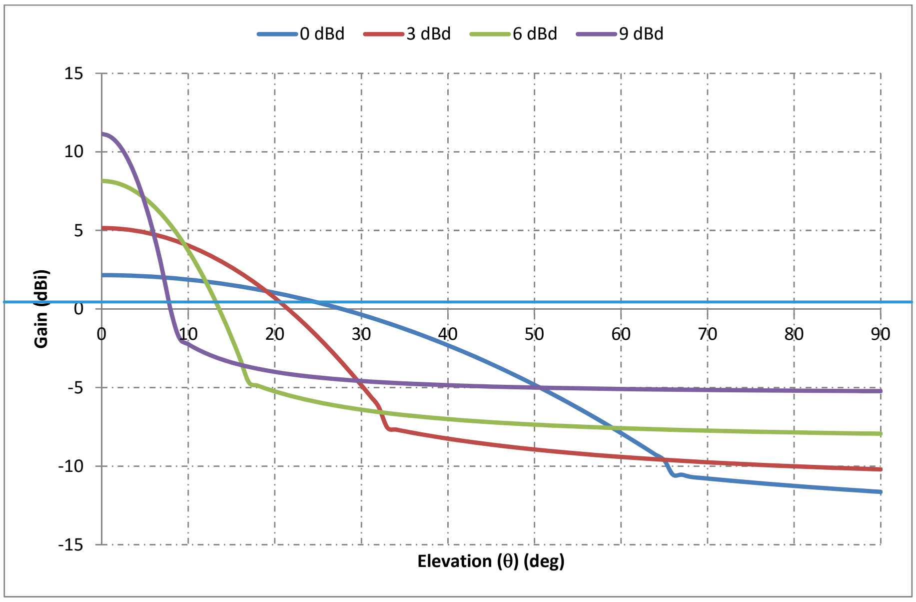
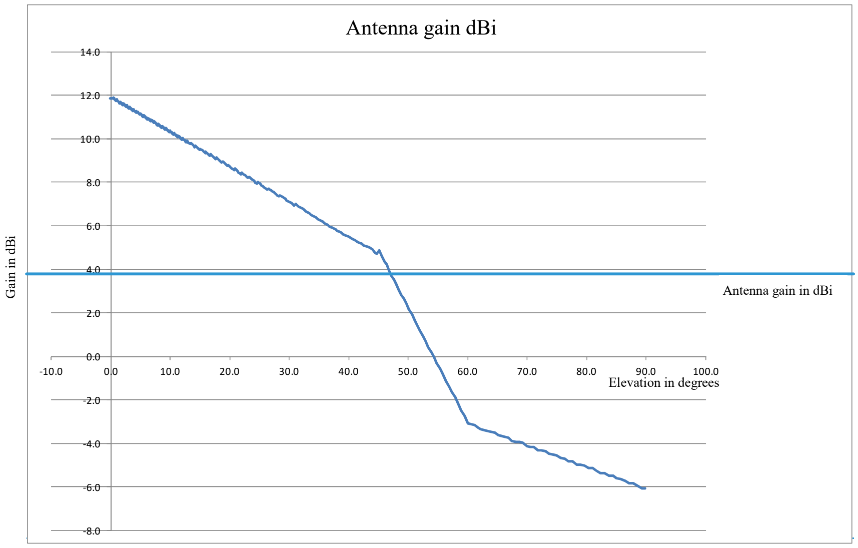


FIGURE A7-4

Mask for "Ideal" antenna



6 VHF data exchange by satellite

VHF data exchange by satellite should use the channels designated for satellite in Table A1-1 of Annex 1 and should be in accordance with this Recommendation. This is further described below.

6.1 General

6.1.1 VHF data exchange system satellite component

The VHF data exchange VDE satellite component is an effective means to extend the VDES to areas outside of coastal VHF coverage. Hereafter, the satellite component is referred to as the VDE-SAT.

Satellite communications is able to deliver information in a broadcast, multicast or unicast mode to a large number of ships, i.e. efficiently addressing many ships using only minimal radio spectrum resources.

The VDE-SAT provides a communication channel that is complementary to the terrestrial components of the VDES system (i.e. coordinated with terrestrial VDE, ASM and AIS functionalities and their supporting systems).

6.1.2 Applications

Continuous exchanges with the maritime community will provide further insight into the priorities, quality of service, security, integrity and other requirements of future VDES services.

There is a large population of smaller size ships which have no satellite communication equipment on board, but do have regular VHF/AIS reception equipment that could benefit from the services mentioned above. This would be of particular benefit for vessel populations in areas with limited shore based infrastructure.

Using low cost satellite reception technology, VDE-SAT can address a large population of ships and offer services for small vessels, fishing vessels and recreational vessels.

6.2 Overall architecture, operational characteristics and assumptions

6.2.1 Architecture

The VHF data exchange system architecture is shown in Figure. A7-5 below. The VDE-SAT is composed of one or more satellites transmitting and receiving in the maritime VHF bands this is the space segment.

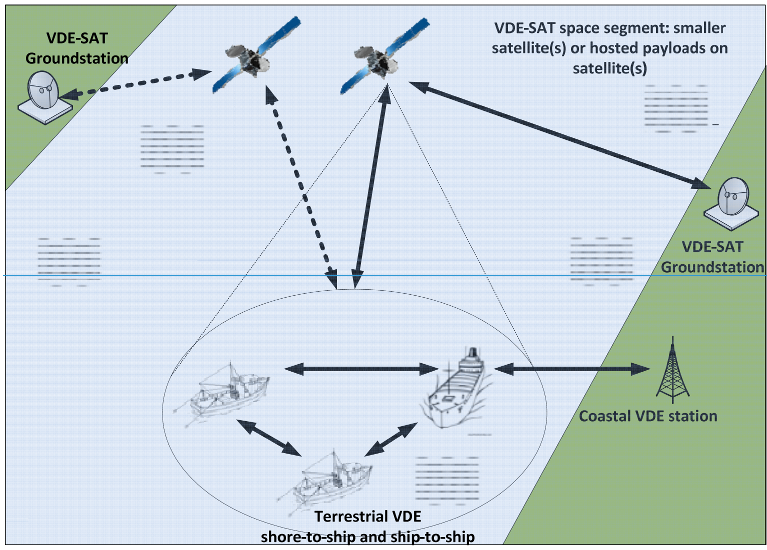
Due to the frequencies used, it is likely that VDE-SAT will consist of low-earth orbiting (LEO) or medium earth orbiting (MEO) satellites. VDE-SAT could also consist of hosted payloads on spacecraft in such orbits.

The VDE-SAT user terminals may be integrated in ship-borne VDES equipment. This is called the user segment. These terminals could be integrated in the terrestrial VDE equipment along with ASM and AIS functionalities. Also VDE-SAT receive only terminals can be considered: these would provide a very cost effective means to disseminate maritime information to smaller ships outside terrestrial VHF coverage, for example in areas with limited shore based infrastructure.

There will be a ground segment which consists of one of more ground stations that will send and receive maritime information to/from ships for further processing or dissemination, via the space segment. Communication between the coastal VDE station, maritime information provider, VDE-SAT ground station and feeder link is not part of the VDES architecture.

FIGURE A7-5

VHF data exchange-satellite component architecture



6.2.2 Operational characteristics

The VDE-SAT should complement the VDE terrestrial in areas in which no terrestrial VDE coverage is available, i.e. at the high-seas.

The VDE-SAT should provide a downlink capability (i.e. allow to send information from a ground station to one or more ships). Note that VDE-SAT will likely use its specific unicast, multicast or broadcast capability which is inherent in a satellite downlink.

The VDE-SAT should provide an uplink capability (i.e. allow a ship to send information to the satellite, for further relaying to a ground station).

As VDE-SAT will be based on LEO or MEO satellite(s), provisions will need to be taken for the discontinuous contact that ships will have with individual satellites. Furthermore, if there are multiple VDE-SAT satellites or payload footprints that overlap, some coordination between them may be required.

It is proposed that VDE-SAT supports priority, pre-emption and precedence for different services; this could be mapped into different downlinks.

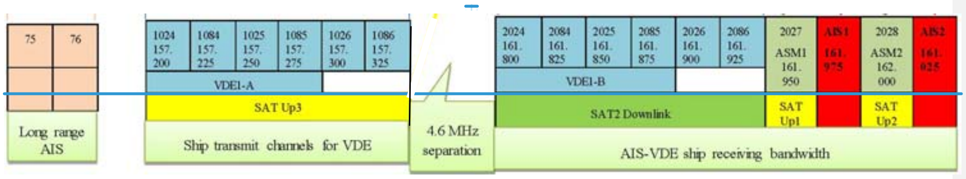
6.3 Technical characteristics

6.3.1 VHF data exchange-satellite channels and spectrum

The VDE-SAT downlink should be used for data downlink from the satellite to vessels in a broadcast, multicast or unicast manner. The VDE-SAT should also provide data uplink from vessels to satellites using one or several multiple-access schemes. The VHF data exchange system via satellite uses the channel allocation shown in Figure. A7-6.

FIGURE A7-6

VHF data exchange system channel allocation



6.3.1.1 SAT downlink

The satellite downlink frequency spectrum consists of six 25 kHz channels (2024 to 2086). These channels may be bundled into one 150 kHz channel to reduce the guard band (needed due to the frequency Doppler shift of incoming signals from LEO satellites), increase the throughput, and more importantly, improve the power efficiency of the satellite power amplifier (avoiding multi-carrier transmission which typically requires a larger output back-off) (refer to § 5.1.3).

Due to the PFD limit imposed on the VDE-SAT downlink (as part of sharing the frequencies with land mobile), a certain level of redundancy (in the form of frame repetition, forward error correction or higher layer redundancy) is implemented in the VDE-SAT protocol in order to mitigate the error and enhance the data detection probability.

The VDE-SAT downlink signal also includes repeated known symbols (e.g. pilots, preamble, post-amble) to facilitate signal detection and synchronization as well as possible interference mitigation and channel estimation. In order to avoid unwanted in-band spectral lines, the data symbols are scrambled with a known sequence. The example in § 6.4.2.19 concludes that a downlink data rate of 240 kbits/s is possible.

The signal level generated by the satellite should be kept below the PFD mask limit (referred to the Earth's surface) specified in Table A7-2 below. Note that this is based on coordination with terrestrial VHF services and that the PFD level refers to the vertical component of radiation normal to the Earth's.

TABLE A7-2

Power flux-density mask

$$\theta^\circ = earth - satellite\ elevation\ angle$$

$$PFD(\theta^\circ)_{(dBW/(m^2*4\ kHz))} = \begin{cases} -149 + 0.16 * \theta^\circ & 0^\circ \le \theta < 45^\circ; \\ -142 + 0.53 * (\theta^\circ - 45^\circ) & 45^\circ \le \theta < 60^\circ; \\ -134 + 0.1 * (\theta^\circ - 60^\circ) & 60^\circ \le \theta \le 90^\circ. \end{cases}$$

This PFD mask is to ensure that there is no harmful interference caused by the satellite downlink on non-maritime terrestrial services sharing the same frequency (ensuring in-band carrier-to-interference requirements of terrestrial service receivers).

6.3.1.2 SAT 3 uplink

The frequency spectrum corresponding to 6 lower VDE channels (starting from Channel 1024) are used for satellite data uplink. Compared to the AIS channels, and long range AIS, these 6 channels provide a significant data uplink capability via satellite.

The access scheme protocol for data uplink via satellite is designed to take into account the entire satellite field of view and to maximize the probability of message detections by avoiding message collisions.

6.3.2 Rationale of channel allocation for VHF data exchange-satellite

The frequency plan for the entire VDES, as depicted in Fig. A7-6 above, facilitates a realistic implementation of the proposed system in co-existence with, and complementing, the current AIS. The following points regarding the frequency plan are highlighted:

– The requirements for VDES concentrate the reception frequencies on board of the ship to a limited range of 250 kHz at the upper maritime VHF band. This provides an efficient implementation of VDES on-board receivers by narrowing the input filter bandwidth, reducing potential impairments due to other activities within the maritime VHF band;

– The VDE-SAT downlink shares the same frequency range as the terrestrial VDE and AIS. This allows sharing the same antenna as well as the receiver front-end design;

– Satellite and shore reception frequencies of shipborne VDE signals occupy the lower end of the VHF maritime band. This allows for a complementary service close to the shore and at the high sea while sharing the same spectrum. The frequency separation between the upper and lower spectra (with 4.6 MHz separation) provides an acceptable level of isolation between VDES receiving chain and the VDE ship-borne transmitters;

– The frequency separation between the uplink and downlink allows hosting VDE-SAT transmitter and receiver on the same satellite which allows for a more cost-effective satellite mission concepts (i.e. reduce number of satellites, improved efficiency and possible interactivity).

6.4 Example VHF data exchange system satellite implementation

The following example VDES satellite implementation fits the PFD angular mask and supports the requirements of this Recommendation.

6.4.1 Determine the VHF data exchange system satellite orbital characteristics

The following VDES satellite implementation is considered. The satellite orbital characteristics that are needed to support this application are determined as follows.

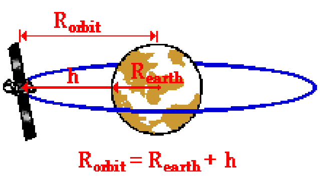
6.4.1.1 Determine the satellite's orbit

The example VDES satellite employs a polar orbit at a height of 550 km above the surface of the Earth. The velocity, acceleration and orbital period of the satellite are determined, given: $M_{earth} = 5.98 \times 10^{24}$ kg, $R_{earth} = 6.37 \times 10^{6}$ m.

The satellite's orbit and the known and unknown parameters are shown in Figure. A7-7 below.

FIGURE A7-7

Satellite orbital characteristics



Known:	Unknown:
$R = R_{earth}$ + height = 6.92×10^{6} m	v
$M_{earth} = 5.98 \times 10^{24}$ kg	a
$G = 6.673 \times 10^{-11}$ N m²/kg²	T

The radius of a satellite's orbit can be determined from the Earth's radius and the height of the satellite above the Earth. As shown in Figure. A7-7, the radius of orbit for a satellite is equal to the sum of the Earth's radius and the height above the Earth. These two quantities are added to yield the orbital radius. The 550 km altitude is first converted to 0.550×10^6 m and then added to the radius of the Earth.

Determine the velocity of the satellite,

$v = \text{SQRT}((G \times M_{central}) / R)$

$v = \text{SQRT}((6.673 \times 10^{-11}\ N\ m^2/kg^2) \times (5.98 \times 10^{24}\ kg) / (6.92 \times 10^6\ m))$

$v = 7.594 \times 10^3$ m/s.

Determine the acceleration of the satellite,

$a = (G \times M_{central})/R^2$

$a = (6.673 \times 10^{-11}\ N\ m^2/kg^2) \times (5.98 \times 10^{24}\ kg) / (6.92 \times 10^6\ m)^2$

$a = 8.333$ m/s^2.

Determine the orbital period of the satellite,

$T = \text{SQRT}((4 \times \pi^2 \times R^3) / (G \times M_{central}))$

$T = \text{SQRT}((4 \times (3.1415)^2 \times (6.92 \times 10^6\ m)^3) / (6.673 \times 10^{-11}\ N\ m^2/kg^2) \times (5.98 \times 10^{24}\ kg))$

$T = 5725.7$ s = 1.59 h.

6.4.2 VHF data exchange system satellite antenna and downlink characteristics

A directional vertically polarized Yagi-Uda antenna is used for communicating with ships' vertical antennas and also for conformance with the PFD angular mask.

6.4.2.1 Determine the Earth's rotation at the equator between each satellite orbit

The period of the Earth T_e is approximately 24 hours (86.4×10^3 s), the radius of the Earth R_e is 6.37×10^6 m and the circumference of the Earth (distance around the equator) is $C_{earth} = 2 \times (3.1415) \times (6.37 \times 10^6\ m) = 40.0239 \times 10^6$ m. Therefore, in each pass of the satellite, the Earth will have rotated at the equator by $ROT_{equator} = C_{earth} \times T / T_e = 40.0239 \times 10^6\ m \times 5725.7\ s / 86.4 \times 10^3\ s = 2.6524 \times 10^6$ m = 2652.4 km.

6.4.2.2 Determine the slant distance to the Earth's horizon

The slant distance D_s from the satellite to the Earth's horizon is $D_s = \text{SQRT}(R^2 - R_e^2) = \text{SQRT}((6.92 \times 10^6\ m)^2 - (6.37 \times 10^6\ m)^2) = 2.7036 \times 10^6$ m = 2 703.6 km.

6.4.2.3 Determine the slant downward tilt angle to the Earth's horizon

The satellite's downward tilt angle to the Earth's horizon is:

$\theta_d = 90° - \sin^{-1}(R_e / R) = 90° - \sin^{-1}(6.37 \times 10^6\ m / 6.92 \times 10^6\ m) = 90° - 67° = 23$ degrees.

6.4.2.4 Determine the width of the antenna coverage path

The example VDES satellite antenna pattern is shown in Figure. A7-8 below. The beam width (±3 dB) of the antenna is 80 degrees. The width of the satellite antenna's coverage path is:

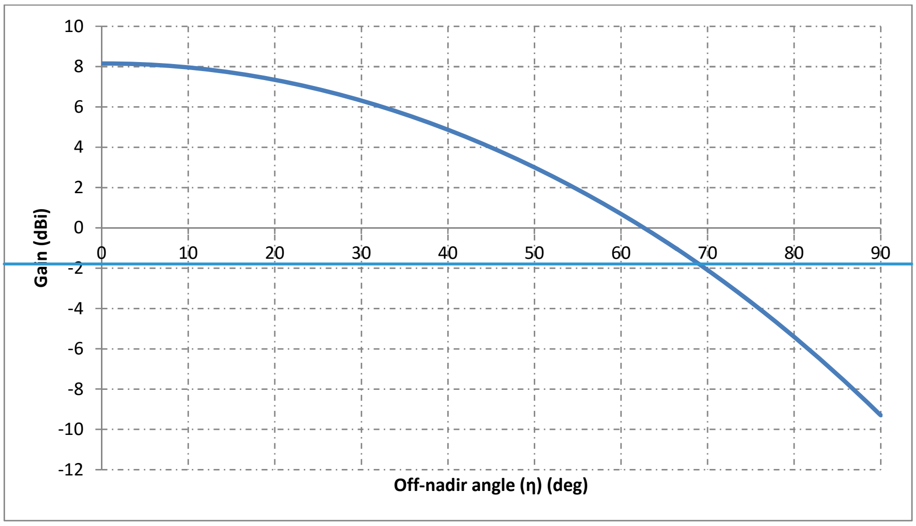
$W_c = 2 (D_s \cos(90° - \theta_a/2))$

$W_c = 2 \times 2.7036 \times 10^6\ m \times \cos(90° - 80° / 2) = 3.4757 \times 10^6\ m = 3\ 475.6$ km.

NOTE: From 4.2.1 that since $ROT_{equator}$ = 2 652.4 km, this antenna beamwidth (θ_d = 80°) is sufficiently wide for contiguous earth coverage by one satellite every 24 hours. This vertically-polarized Yagi-Uda antenna is pointed in the forward direction with an optimized downward tilt angle to provide the vertical component of radiation for reception by ships' vertical dipole antennas.

FIGURE A7-8

Example VDES satellite antenna pattern



6.4.2.5 Determine the maximum Doppler frequency shift (f_d) between the satellite and ships in the satellite's antenna coverage area

The maximum Doppler frequency shift (f_d) between the satellite and a ship will occur when the relative velocity between them is a maximum, i.e. when the ship is situated on the satellite's earth horizon. Note that the coverage for this satellite is only in the forward direction and that the satellite's antenna pattern will cover ships in the range of 23 degrees (earth's horizon) downward from the satellite's velocity vector. Therefore, the maximum Doppler shift is f_d (max) = f_{VDES} (v/c) × cos θ_d = 162 × 10^6 (7.594 × 10^3)/(3 × 10^8) × cos 23° = 3 775 Hz. The satellite transmitter frequency should be reduced by half of f_d (max) to provide a range of ±1 887.5 Hz in the coverage area.

Determine the optimum downward tilt angle for the satellite VDES antenna for coverage of ships in the forward direction

From the VDES satellite antenna characteristics in Figure A7-8 above, note that the response is flat to approximately 12°. This supports an additional downward tilt of 12° below the horizon of 23° for an optimized total downward tilt angle of 35 degrees below the line that is tangent to the satellite's orbital path. This provides a sufficient vertical radiation component for ships in the coverage area.

6.4.2.6 Consideration of the angular power flux-density mask limits for transmission by the VHF data exchange system satellite

The PFD angular mask (the maximum allowable PFD in dB(W/(m^2 × 4 kHz)) as a function of the elevation angle from the Earth), is shown in Table A7-2 of § 6.3.1. Note that the PFD mask at 0°

(horizon) is −149 dB(W/(m² × 4 kHz)), at 45° elevation is −142 dB(W/(m² × 4 kHz)), at 60° elevation is −134 dB(W/(m² × 4 kHz)) and at 90° (overhead) is −131 dB(W/(m² × 4 kHz)).

Note also that since the PFD mask level refers to the vertical component of radiation normal to the Earth's surface, the polarization loss (≈ 3 dB @ 45° elevation angle) based on the angular relationship between the vertical axis of the satellite antenna and the Earth's surface should be considered in the determination of the satellite VDES transmitter power.

6.4.2.7 Determine the power flux density levels at elevations of 0°, 10°, 30°, 60° and 90° when the power flux density level at 45° elevation is set to −142 dB(W/(m² × 4 kHz))

This section confirms that the elevation angle of 45° is the CPA (closest point of approach) between the PFD mask and the actual radiated VDES space-earth downlink signal.

Calculations of the slant ranges and elevation angles note from the previous calculations that the slant range from the satellite earth horizon is 2 703.6 km. The results of these calculations are shown in Table A7-3 below. Note that the "orbital angle" (the angle of rotation of the satellite's orbit above the Earth) is used as a reference for geometric calculations (angles and distances) and for time keeping (elapsed time from the horizon to the point of rotation).

The slant ranges from the satellite to an earth station are determined from the law of cosines (c = SQRT ($a^2 + b^2 + c^2 - 2ab\cos(C)$), where c = slant range, $a = R_e + h$, $b = R_e$ and C = the satellite orbital angle. The calculations start with C = 23° (the angle to the horizon) and proceed to C = 0° (the directly above/below position), shown in Table A7-3.

To find the elevation angles, reference angles are determined from the inverse law of cosines ($C = \cos^{-1}((a^2 + b^2 + c^2)/(2ab))$ where C = the reference angle between the slant range (line of observation) and the Earth radius (line from the Earth station to the centre of the Earth), a = slant range, b = earth radius and $c = R_e + h$. The elevation angles for the Earth stations are determined by subtracting 90° from the reference angles, also shown in Table A7-3 below.

6.4.2.8 Determine reference levels based on the 45° elevation angle

From Table A7-2, the slant range to the satellite at 45° elevation is 748.3 km and the PFD at 45° elevation is set to the mask limit of −142 dB(W/(m² × 4 kHz)). Since the relative angle of the satellite antenna (down tilted by 35°) in that direction is approximately (45° − 35°) = 10°, the gain of the satellite antenna in that direction, from Fig. A7-19, is 8 dB. These values were used as the set point values (the 0 dB reference levels) to calculate the PFD levels for the other elevation angles.

6.4.2.9 Determine the power flux density level for the elevation angle of 0°

The slant range at 0° (horizon) is 2 703.6 km, the satellite relative angle to the horizon is −23°, the satellite antenna relative angle with a 35° down tilt is (35° − 23°) = 12° and the gain, from Figure A7-19, is 8 dB. Since the relative range loss is (20 log (748.3/2 703.6)) = −11.2 dB, the PFD at 0° is 11.2 dB below the 45° level (−142 − 11.2) = **−153.2 dB(W/(m² × 4 kHz))** which is (−149 − (−153.2)) = 4.2 dB below the 0° mask limit.

6.4.2.10 Determine the power flux density level for the elevation angle of 10°

The slant range at 10° elevation is 1 818.4 km, the satellite relative angle to the horizon is −23°, the satellite antenna relative angle with a 35° down tilt is (35° − 23°− 10°) = 2° the gain, from Fig. A7-19, is 8 dB (the same as the reference), the relative range loss is 20 log (748.3/1 818.4) = −7.7 dB and thus the PFD at 10° is (−142 − 7.7) = **−149.7 dB(W/(m² × 4 kHz))** which is 2.3 dB below the 10° mask limit of −147.4 dB(W/(m² × 4 kHz)).

6.4.2.11 Determine the power flux density level for the elevation angle of 30°

The slant range at 30° elevation is 993.5 km, the satellite relative angle to the horizon is –23°, the satellite antenna relative angle with a 35° down tilt is (35° – 30°) = 5° the gain, from Fig. A7-19, is 8 dB (the same as the reference), the relative range loss is 20 log (748.3/993.5) = –2.5 dB and thus the PFD at 30° is (–142 – 2.5) = **–144.5 dB(W/(m² × 4 kHz))** which is 0.3 dB below the 10° mask limit of –144.2 dB(W/(m² × 4 kHz)).

6.4.2.12 Determine the power flux density level for the elevation angle of 60°

The slant range at 60° elevation is 632.7 km, the satellite relative angle to the horizon is –23°, the satellite antenna relative angle with a 35° down tilt is (35° – 60°) = –18° the gain, from Fig. A7-19, is 7.5 dB (0.5 dB below the reference), the relative range is 20 log (748.3/632.7) = +1.5 dB (1.5 dB above the reference) and thus the PFD at 60° is (–142 – 0.5 + 1.5) = **–141.0 dB(W/(m² × 4 kHz))** which is 7.0 dB below the 60° mask limit of –134.0 dB(W/(m² × 4 kHz)).

6.4.2.13 Determine the power flux density level for the elevation angle of 90°

The slant range at 90° (overhead) is the satellite altitude of 550 km, the gain of the satellite antenna in that direction, from Fig. A7-19, with a down tilt of 35 degrees is the gain at (35° – 90°) = –55 degrees is 2 dB (6 dB below the reference), the relative range factor is 20 log (748.3/550) = +2.7 dB (2.7 dB above the reference) and thus the PFD at 90° is (–142 – 6 + 2.7) = **–145.3 dB(W/(m² × 4 kHz))** which is 14.3 dB below the 90° mask limit of –131 dB(W/(m² × 4 Hz)).

The PFD values for elevation angles from 0° to 90° are shown in Table A7-3 below.

TABLE A7-3

Power flux density for various elevation angles

Orbital angle (degrees)	Elapsed time from horizon (seconds)	Slant range (km)	Reference angle (degrees)	Elevation angle (degrees)	PFD (actual/mask/margin, in dB(W/(m² × 4 kHz)))
23	0	2 703.6	90	0	–153.2/–149/4.2
22	15.9	2 592.7	90.5	0.5	–152.8/–148.9/3.9
21	31.8	2 481.6	91.0	1.0	–152.4/–148.8/3.6
20	47.7	2 370.5	93.2	3.2	–152/–148.5/3.5
19	63.6	2 259.6	94.4	4.4	–151.6/–148.3/3.3
18	79.5	2 148.8	95.6	5.6	–151.2/–148.1/3.1
17	95.4	2 038.3	97.0	7.0	–150.7/–147.9/2.8
16	111.3	1 928.1	98.4	8.4	–150.2/–147.7/2.5
15	127.2	1 818.4	100.0	10.0	–149.7/–147.4/2.3
14	143.1	1 709.2	101.6	11.6	–149.2/–147.1/2.1
13	159.0	1 600.6	103.5	13.5	–148.6/–146.8/1.8
12	175.0	1 493.0	105.5	15.5	–148/–146.5/1.5
11	190.9	1 386.5	107.8	17.8	–147.4/–146.1/1.3
10	206.8	1 281.4	110.3	20.3	–146.7/–145.8/0.9
9	222.7	1 178.1	113.2	23.2	–145.9/–145.3/0.6

TABLE A7-3 (*end*)

Orbital angle (degrees)	Elapsed time from horizon (seconds)	Slant range (km)	Reference angle (degrees)	Elevation angle (degrees)	PFD (actual/mask/margin, in dB(W/(m² × 4 kHz)))
8	238.6	1 077.3	116.6	26.6	–145.2/–144.7/0.5
7.145	252.2	993.5	120.0	30.0	–144.5/–144.2/0.3
7	254.5	979.6	120.6	30.6	–144.3/–144.1/0.2
6	270.4	886.3	125.3	35.3	–143.5/143.35/0.15
5	286.3	798.7	131.0	41.0	–142.5/–142.4/0.1
4.38	296.1	748.3	135.0	45.0	–142/–142/0 *(reference)*
4	302.2	719.2	137.8	47.8	–141.7/–140.5/1.2
3	318.1	650.6	146.2	56.2	–141.5/–136.1/5.4
2.7	322.9	632.7	150.0	60.0	–141/–134/7
2	334.0	596.8	156.1	66.1	–141.8/–133.4/8.4
1	349.9	562.1	167.6	77.6	–143.1/–132.2/10.9
0	365.8	550.0	180	90	–145.3/–131/14.3

Notes to Table A7-3:

1. When the PFD level is set to the mask limit of –142 dB (W/(m2 × 4 kHz)) at 45° elevation angle, the PFD levels at all other elevation angles are below the mask.

2. The maximum PFD level is –141 dB (W/(m2 × 4 kHz)) at 60° elevation angle, which is 7 dB below the mask limit level of –134 dB(W/(m2 × 4 kHz)).

6.4.2.14 Consider the shipborne VHF data exchange system antenna and receiver characteristics

The shipborne antenna and receiver characteristics are considered, along with the satellite radiated PFD levels, to determine the performance of the example VDES satellite downlink.

6.4.2.15 Specify the shipborne VHF data exchange system antenna characteristics

The available shipborne antenna options are comprised of stacked vertical dipole elements of various lengths and gain values, were previously shown in Fig. A7-3 in § 5.3. This analysis considers the 0 dBd antenna because it has the best performance for the elevation angles required for satellite detection.

6.4.2.16 Determine the shipborne VHF data exchange system receiver characteristics

The shipborne VDES receiver characteristics and the coordination levels for the terrestrial service are considered, and the set of metrics in Table A7-4 below are used to determine a reference value of *C*/*N* (carrier-to-noise ratio) for the example shipborne VDES receiver.

TABLE A7-4

Metrics for considering ITU-R coordination levels and calculating *C/N* in a VDES receiver

Power received (referred to the Rx antenna) by a shipboard VHF receiver (reference 25 kHz channel):
Power received (linear formula): $P_r = GE^2c^2/480\pi^2f^2$, where
G = gain of a half-wavelength (λ/2) dipole antenna = 1.64
E = field strength = 4×10^{-6} V/m (4 μV/m = +12 dBμ)
c = speed of light in free space = 3×10^8 m/s
f = VDES downlink frequency = 161.9×10^6 (161.9 MHz)
λ = 1.852 m (at 161.9 MHz)
$P_r = 19.02 \times 10^{-15}$ W = –137.2 dBW = –107.2 dBm
The logarithmic formula can also be used to calculate P_r (dBm):
P_r (dBm) = 42.8 – 20 log F + 20 log E + G, where
G = antenna gain in dBi = 2.1 dBi (2.1 dB over isotropic)
F = frequency in MHz = 161.9
P_r (dBm) = 42.8 – 44.1 – 108 + 2.1 = –107.2 dBm (–137.2 dBW)
PFD = dB(E) –153.72 = 12–153.72 = –141.72 dB(W/(m² × 4 kHz)) from a vertically-polarized source
A_e = effective area for a dipole antenna = $0.13\lambda^2$ = 0.446 m²
P_r (25 kHz channel) = PFD + 10 log A_e + 10 log (25/4) = –141.7 – 3.5 +8 = –137.2 dBW = –107.2 dBm
Power received by a shipboard VDES receiver (reference 150 kHz channel):
Noise floor in a 150 kHz bandwidth: kTB = 10 log ((1.38×10^{-23}) (290) (150×10^3))= –152.2 dBW
Rx carrier power (reference) in a 150 kHz bandwidth: C = 10 log ((19.02×10^{-15}) (150/25))= –129.4 dBW
Applying adjustments for cable loss (2dB) and Rx noise figure (4 dB), the C/N calculation follows:
C/N (150 kHz bandwidth): C/N_{ref} = (–129.4 – 2) – (–152.2 + 4) = 16.8 dB (Rx 0 dBd antenna, 0° elevation)
NOTE: These calculations serve to confirm the applicability of the metrics and reference levels.

6.4.2.17 Determine the values of carrier to noise vs. elevation angle for the shipborne VHF data exchange system receiver

Based on the C/N reference level (C/N_{ref}) from Table A7-4, determine the C/N for the PFD values and elevation angles in Table A7-3, taking into account the shipborne antenna angular gain values for the 0 dBd antenna in Fig. A7-3. For this antenna, G_a = 2.1 dBi at 0° elevation angle.

$C/N = C/N_{ref} - (-142 - \text{PFD} - (2.1 - G_a))$, where G_a = shipborne antenna gain at the elevation angle.

At 0° elevation, C/N = 16.8 – (–142 – (–153.2) – (2.1 – 2.1)) = 5.6 dB

At 10° elevation, C/N = 16.8 – (–142 – (–149.7) – (2.1 – 1.9)) = 8.9 dB

At 30° elevation, C/N = 16.8 – (–142 – (–144.5) – (2.1 – (–0.3)) = 11.9 dB

At 45° elevation, C/N = 16.8 – (–142 – (–142) – (2.1 – (–3.5)) = 11.2 d.

At 60° elevation, C/N = 16.8 – (–142 – (–141) – (2.1 – (–7.6)) = 8.1 dB

At 90° elevation, C/N = 16.8 – (–142 – (–145.3) – (2.1 – (–11.6)) = –0.2 dB.

The C/N values for elevation angles from 0° to 90° are shown in Table A7-5 below.

TABLE A7-5

Carrier to noise and power flux density for various elevation angles

Orbital angle (degrees)	Elapsed time from horizon (seconds)	Slant range (km)	Elevation angle (degrees)	PFD (actual/mask/margin, in dB(W/(m² × 4 kHz)))	*C/N* ship receiver (dB)
23	0	2 703.6	0	−153.2/−149/4.2	5.6
22	15.9	2 592.7	0.5	−152.8/−148.9/3.9	6
21	31.8	2 481.6	1.0	−152.4/−148.8/3.6	6.4
20	47.7	2 370.5	3.2	−152/−148.5/3.5	6.8
19	63.6	2 259.6	4.4	−151.6/−148.3/3.3	7.2
18	79.5	2 148.8	5.6	−151.2/−148.1/3.1	7.6
17	95.4	2 038.3	7.0	−150.7/−147.9/2.8	8
16	111.3	1 928.1	8.4	−150.2/−147.7/2.5	8.5
15	127.2	1 818.4	10.0	−149.7/−147.4/2.3	8.9
14	143.1	1 709.2	11.6	−149.2/−147.1/2.1	9.4
13	159.0	1 600.6	13.5	−148.6/−146.8/1.8	9.7
12	175.0	1 493.0	15.5	−148/−146.5/1.5	10.2
11	190.9	1 386.5	17.8	−147.4/−146.1/1.3	10.8
10	206.8	1 281.4	20.3	−146.7/−145.8/0.9	10.9
9	222.7	1 178.1	23.2	−145.9/−145.3/0.6	11.5
8	238.6	1 077.3	26.6	−145.2/−144.7/0.5	11.8
7.145	252.2	993.5	30.0	−144.5/−144.2/0.3	11.9
7	254.5	979.6	30.6	−144.3/−144.1/0.2	11.9
6	270.4	886.3	35.3	−143.5/143.35/0.15	11.9
5	286.3	798.7	41.0	−142.5/−142.4/0.1	11.7
4.38	296.1	748.3	45.0	−142/−142/0 *(reference)*	11.2
4	302.2	719.2	47.8	−141.7/−140.5/1.2	11.0
3	318.1	650.6	56.2	−141.5/−136.1/5.4	8.6
2.7	322.9	632.7	60.0	−141/−134/7	8.1
2	334.0	596.8	66.1	−141.8/−133.4/8.4	4.4
1	349.9	562.1	77.6	−143.1/−132.2/10.9	2.4
0	365.8	550.0	90	−145.3/−131/14.3	−0.2

6.4.2.18 Determine the data rate for elevation angles 0^0 to 60^0 using the digital video broadcast by satellite standards

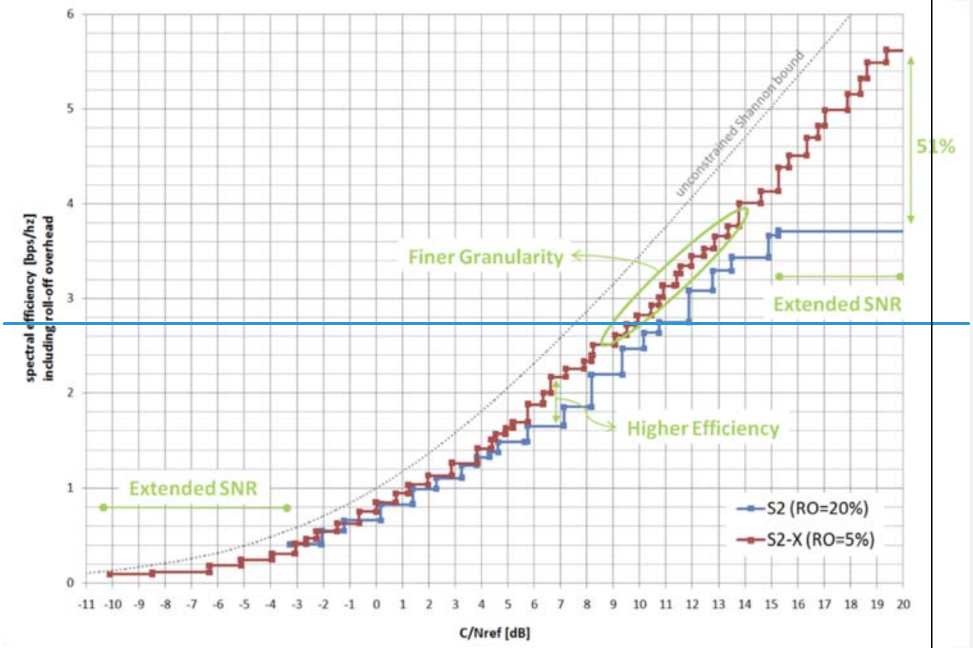
The digital video broadcast standards, by satellite (DVB-S), are designed to provide the maximum utilization of the available bandwidth in a low to moderate *C/N* ratio. The spectral efficiencies for DVB-S2X and DVB-S2 are shown in Figure. A7-9 below.

DVB-S2X is based on the well-established DVB-S2 specification. It uses the proven and powerful LDPC FEC scheme in combination with BCH FEC as outer code and introduces the following additional elements:

– Smaller roll-off options of 5% and 10% (plus 20%, 25% and 35% in DVB-S2)
– A finer gradation and extension of number of modulation and coding modes
– New constellation options for linear and non-linear channels
– Additional scrambling options for critical co-channel interference situations
– Channel bonding of up to 3 channels
– Very Low SNR operation support down to −10 dB SNR; and
– Super-frame option.

FIGURE A7-9

Performance of DVB-S2X and DVB-S2



6.4.2.19 Performance conclusion

From Figure. A7-9 above, it is concluded that the DVB-S2X standard transmission applied to the VDES satellite downlink provides spectral efficiency of 1.6 bps/Hz and a date rate of 240 kbits/s in a 150 kHz bandwidth for $C/N \geq 5$ dB, which, from Table A7-5, includes elevation angles from 0° to 60°.

7 Propagation range predictions for VHF data exchange system terrestrial links

7.1 Introduction

This is an informative annex. The excellent propagation characteristics of AIS are well established and appreciated. It is expected that the ASM will have similar performance to AIS. The propagation range predictions for the 100 kHz VDE ship-to-shore and shore-to-ship links follow below.

7.1.1 Ship-to-shore application

Commenté [JC99]: This could be a level 2, as it doesn't seem to sit only under the Introduction, but as an item on its own – Ship-shore application. Then Shore-Ship application could be moved to level 2 as well.

7.1.1.1 Basis for the coverage assessment

This coverage assessment is based on Recommendation ITU-R P.1546-5 (assuming no ducting), taking into account the antenna height and the seawater propagation path:

Height of antenna (Base Station): 75 m (see graph for various heights)
Transmitter power for ship: 12.5 W
Tx ship antenna gain: 2 dBi (0 dBd)

Rx shore antenna gain: 8 dBi (6 dBd)

P_r: −103 dBm (VDE shore station sensitivity)

7.1.1.2 Purpose for use of the Recommendation ITU-R P.1546-5 propagation curve

Recommendation ITU-R P.1546-5 prescribes the use of the propagation curves (§3 from Annex 5 and Fig. 4 from Annex 2 of ITU-R P.1546-5), see below Figs. A7-10 and A7-11 of this Annex, assuming no ducting and a smooth earth/sea surface. This analysis may be used as a reference point for field test measurements that usually include some ducting, depending on weather, atmospheric conditions, and other factors.

7.1.1.3 Determination of transmitting/base antenna height, h_1

Recommendation ITU-R P.1546-5 specifies (§ 3 of Annex 5) the transmitting/base antenna height, h_1, to be used in calculation depending on the type and length of the path. For sea paths h_1 is the height of the antenna above mean sea level; for land paths h_1 is the height above average terrain.

NOTE: The reference antenna height for the ship's stations h_2 is 10 m.

7.1.1.4 Determination of the minimum field strength (sensitivity threshold) at the VHF data exchange base receiving site

For ship-to-shore:

Power received (linear formula): $P_r = G_r E_r^2 c^2 / 480\pi^2 f^2$

Rearranged: $E_r = \sqrt{(480\pi^2 f^2 P_r / G_r c^2)}$, where

E_r = field strength in V/m

G_r = gain of receiving antenna = 6.3 = 8 dBi

c = speed of light in free space = 3×10^8 m/s

f = VDE ship-to-shore frequency = 1.57×10^8 (157 MHz)

$P_r = 5 \times 10^{-14}$ watts = −133 dBW = −103 dBm

Thus,

$E_r = 3.21 \times 10^{-6}$ = 3.21 µV/m = +10.1 dB µV/m

The logarithmic formula can also be used to calculate P_r (dBm):

P_r (dBm) = 42.8 − 20 log F + 20 log E + G, where

G = antenna gain in dBi = 8 dBi

F = frequency in MHz = 157

P_r (dBm) = 42.8 − 43.9 − 109.9 + 8 = −103 dBm (−133 dBW)

7.1.1.5 Determine the range to the +10.1 dBµ (−103 dBm) coverage limit for a seawater propagation path

Calculate the effective radiated power:

$P_s = P_t + G$

P_t = 10 log 12.5 − 30 = −19 dBkW (19 dB below 1 kW)

G = 2 dBi = +0 dBd (0 dB over a dipole)

Thus P_s = −19 +0 = −19 dBkW e.r.p.

$F_e = F - P_s$ (vertical scale reference for the propagation graph in Fig. A7-10)

F = +10.1 dBµ

P_s = −19 dBkW

Thus F_e = 10.1 − (−19) = +29.1 dB

7.1.1.6 Determine the seaward ship-to-shore coverage range from Fig. A7-10

The +10.1 dBµ (−103 dBm) range is 85 km, which is 46 NM (use h_1 = 75 m).

7.1.1.7 Determine the received signal strength indication values for various other ranges

The reference point received signal strength indication (RSSI) = −103 dBm at a range of 85 km (46 NM) is determined above. For other ranges, the RSSI value is determined from the propagation curve (Figure. A7-10) for the assumed antenna height of 75 m. RSSI values in 10 dB increments above the sensitivity threshold are shown in Table A7-6 below.

TABLE A7-6

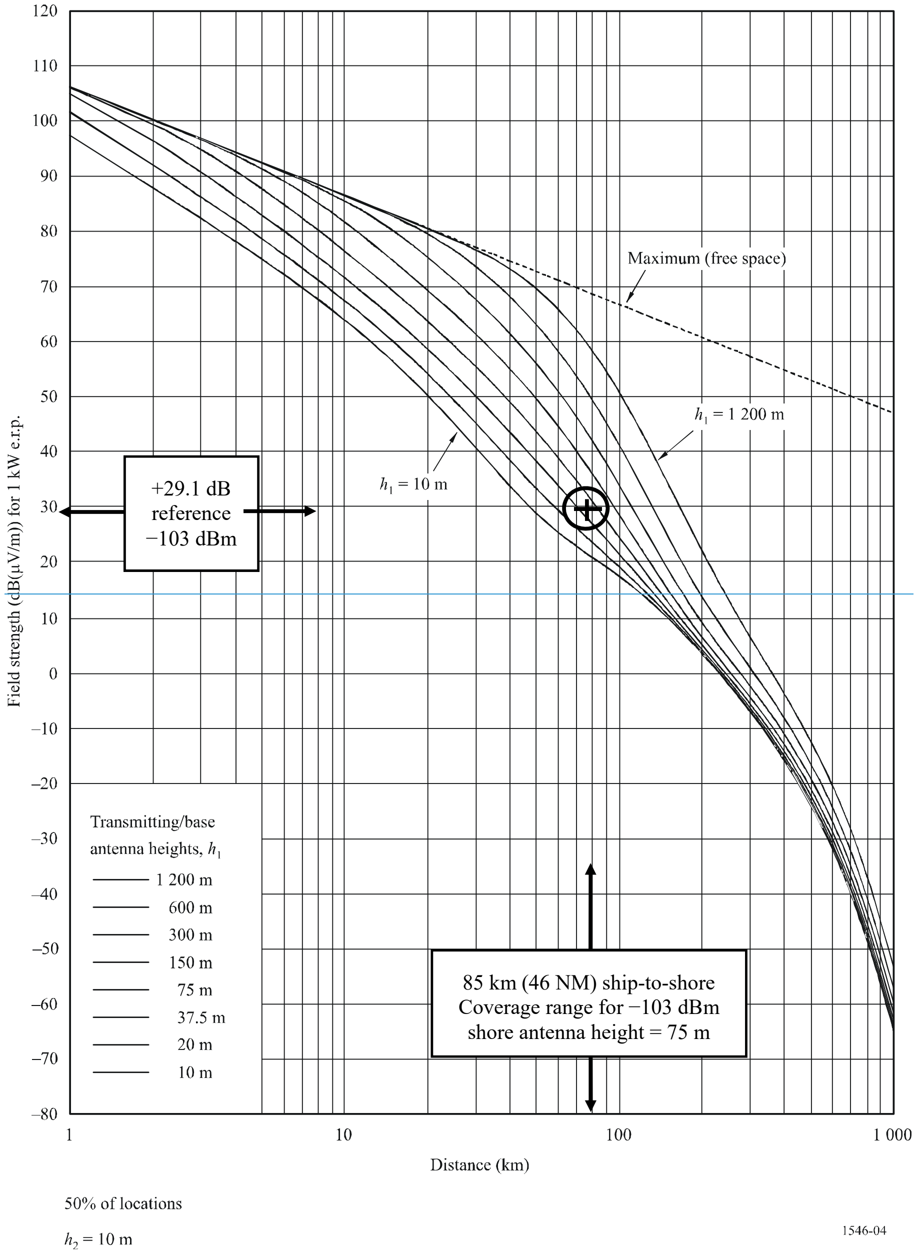
VHF data exchange base station received signal strength indication value vs. distance ship-to-shore

−103 dBm	85 km (46 NM)
−93 dBm	60 km
−83 dBm	40 km
−73 dBm	25 km
−63 dBm	15 km
−53 dBm	8 km
−43 dBm	4.5 km

FIGURE A7-10

FIGURE 4

100 MHz, sea path, 50% time



7.1.2 Shore-to-ship application

7.1.2.1 Basis for the coverage assessment

Referring to § 2 above, we consider the reverse direction, shore-to-ship, signal levels at the ship receiving site, the shore transmitter power of 50 W and the shore-to-ship frequency of 162 MHz:

Height of antenna (VDES Base Station): 75 m (see graph for various heights)

Transmitter power of VDES on shore: 50 W (at base of shore antenna)

Tx shore antenna gain: 8 dBi (6 dBd)

Rx ships antenna gain: 2 dBi (0 dBd)

P_r: –98 dBm (VDE ship station sensitivity)

7.1.2.2 Determination of minimum field strength (sensitivity threshold) at the VHF data exchange ship receiving site

For shore-to-ship:

Power received (linear formula): $P_r = G_r E_r^2 c^2/480\pi^2 f^2$

Rearranged: $E_r = \sqrt{(480\pi^2 f^2 P_r/G_r c^2)}$, where

E_r = field strength in V/m

G_r = gain of receiving antenna = 1.62 = 2.1 dBi

c = speed of light in free space = 3×10^8 m/s

f = VDE shore-to-ship frequency = 1.62×10^8 (162 MHz)

$P_r = 1.58 \times 10^{-13}$ W = –128 dBW = –98 dBm

Thus, $E_r = 11.61 \times 10^{-6}$ V/m = 11.61 µV/m = +21.3 dB µV/m

The logarithmic formula can also be used to calculate P_r (dBm)

P_r (dBm) = 42.8 – 20 log F + 20 log E + G, where

G = antenna gain in dBi = 2.1 dBi

F = frequency in MHz = 162

P_r (dBm) = 42.8 – 44.1 – 98.7 + 2.1 = –98 dBm (–128 dBW).

7.1.2.3 Determine the range to the +21.3 dBµ (–98 dBm) coverage limit for a seawater propagation path

Calculate the effective radiated power:

$P_s = P_t + G$

P_t = 10 log 50 – 30 = –13 dBkW (13 dB below 1 kW)

G = 8 dBi = +6 dBd (6 dB over a dipole)

Thus P_s = –13 + 6 = –7 dBkW e.r.p.

$F_e = F - P_s$ (vertical scale reference for the propagation graph in Fig. A7-11)

F = +21.3 dBµ

P_s = –7 dBkW

Thus F_e = 21.3 – (–7) = +28.3 dB.

NOTE: that since this value of F_e is within 1 dB of the value calculated in § 7.1.1.5 because the reduced sensitivity of the ship station is compensated by the higher power and antenna gain of the shore base station.

7.1.2.4 Determine the seaward shore-to-ship coverage range from Fig. A7-11

The +28.3 dBμ (−98 dBm) range is 85 km, which is 46 NM (use h_1 = 75 m). This is the same as the ship-to-shore coverage range, an ideal balanced two-way coverage, which confirms the proposed choices of antennas and transmitter power values for the shipborne and shore VDES stations.

7.1.2.5 Determine the received signal strength indication values for various other ranges

The reference point: RSSI = −98 dBm at a range of 85 km (46 NM) is determined in § 7.1.1.6 above. For other ranges, the RSSI value is determined from the propagation curve (Figure. A7-11) for the assumed antenna height of 75 m. RSSI values in 10 dB steps above and below the −98 dBm threshold sensitivity for the shipborne VDE receiver are shown in Table A7-7 below.

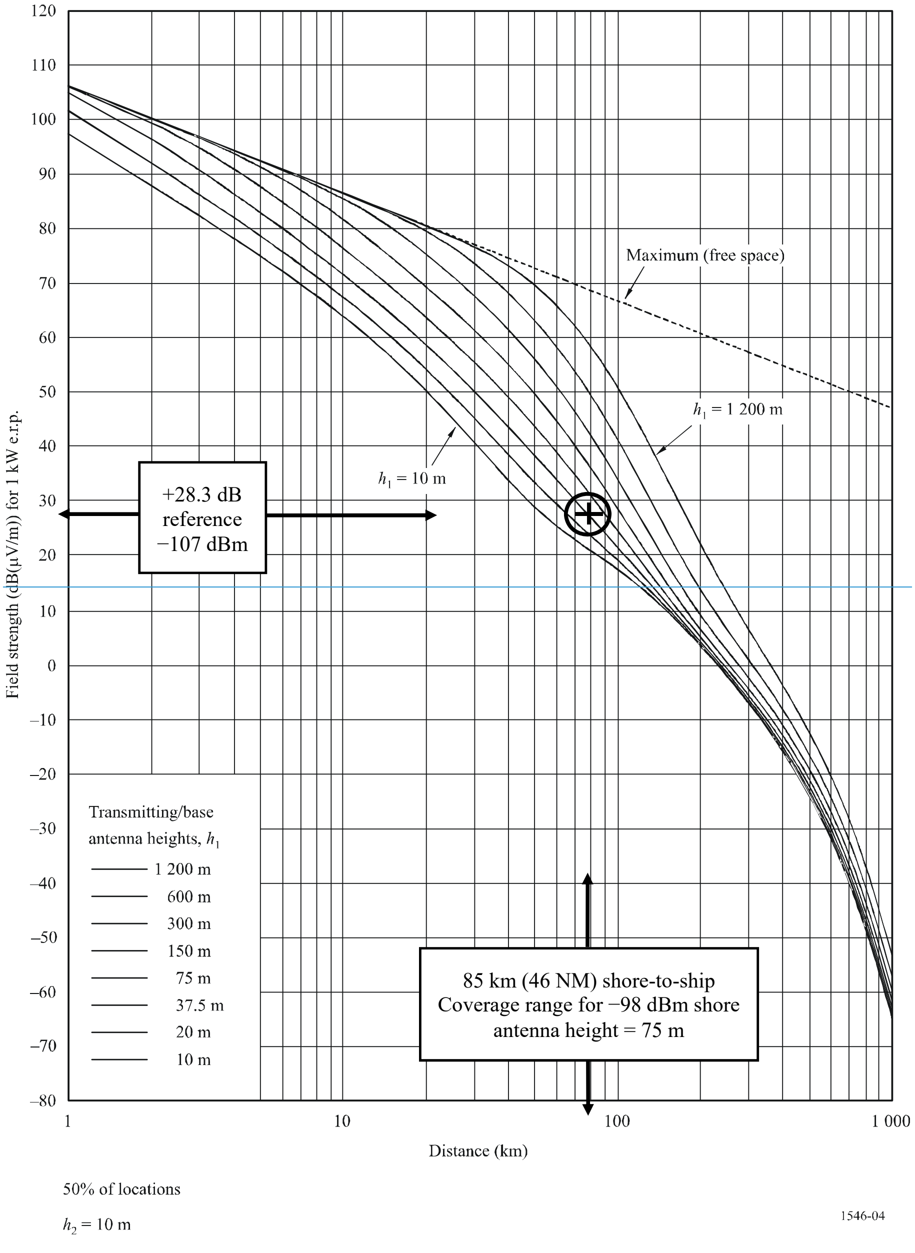
TABLE A7-7

VHF data exchange ship station received signal strength indication value vs. distance shore-to-ship

−118 dBm	170 km
−108 dBm	130 km
−98 dBm	85 km (46 NM)
−88 dBm	60 km
−78 dBm	40 km

FIGURE A7-11

100 MHz, sea path, 50% time



8 Example of VHF data exchange satellite downlink implementation and analysis

8.1 Introduction

This is an informative annex providing an example of implementing the VDE-SAT downlink component and presenting performance results.

8.2 VHF data exchange satellite orbital characteristics

The spacecraft flies in a circular orbit of 600 km and 68° inclination compliant with orbital debris regulations and safe de-orbiting of the spacecraft after its lifetime. The satellite counts with attitude control mechanisms to guarantee a stable antenna pointing in the nadir direction (i.e. satellite-to-Earth).

Under these assumptions Figure. A7-12 shows the elevation (left axis) of the spacecraft as a function of time as seen by a ground terminal during an overhead pass. The right axis of the same figure depicts the signal delay.

FIGURE A7-12

Satellite elevation and delay for the selected orbit as a function of time

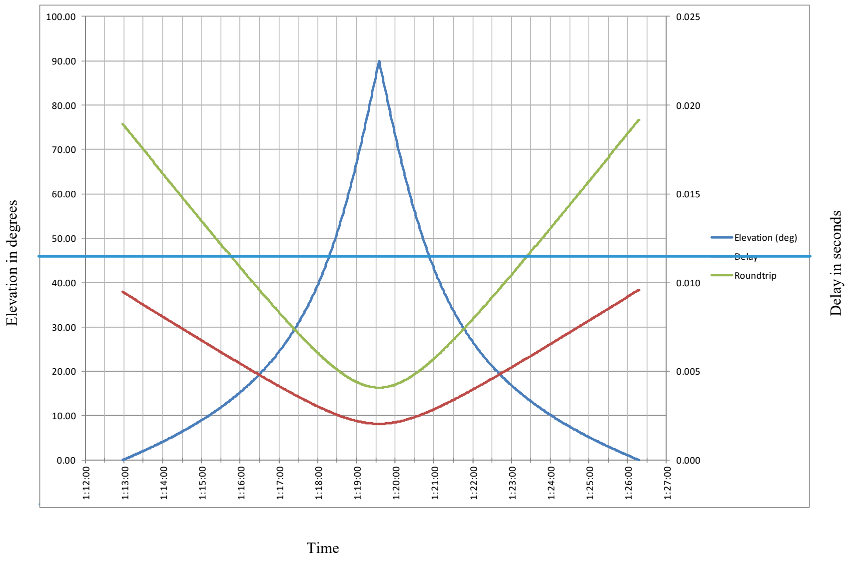


Figure A7-12 shows that the satellite is just over 4 minutes above 30° elevation, thus 9 minutes under 30° elevation from acquisition of signal (AOS) to loss of signal (LOS) for a pass duration of about 13 minutes. The roundtrip delay varies from 19 ms at AOS down to 4 ms at zenith (i.e. 90° elevation). During that pass the Doppler shift varies from −3.73 kHz to +3.73 kHz and the Doppler rate reaches 47 Hz/s at Zenith.

FIGURE A7-13

Pass elevation scheme for selected orbit over 24 hours

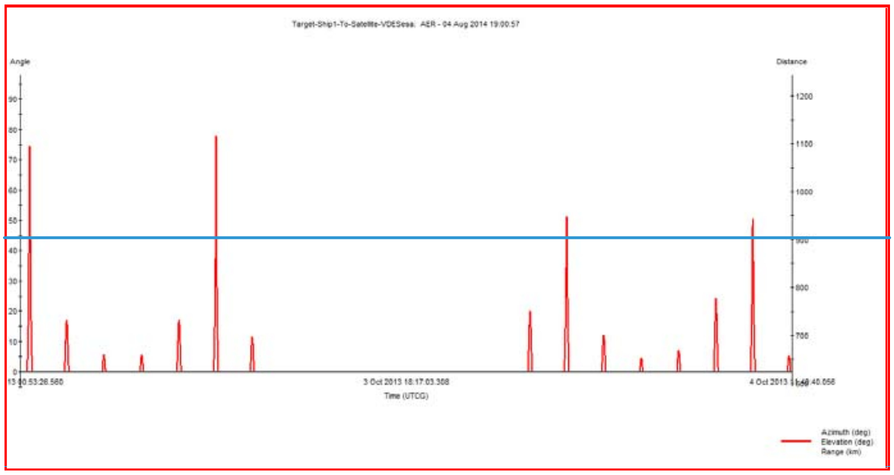


Figure A7-13 illustrates the satellite elevation as a function of time, as seen by a ground terminal at a fixed location in a 24 hour period. As shown the contact periods are short and low. Depending on the latitude, the duration and the number of contact periods will vary (distance is provided in km).

FIGURE A7-14

Satellite field of view

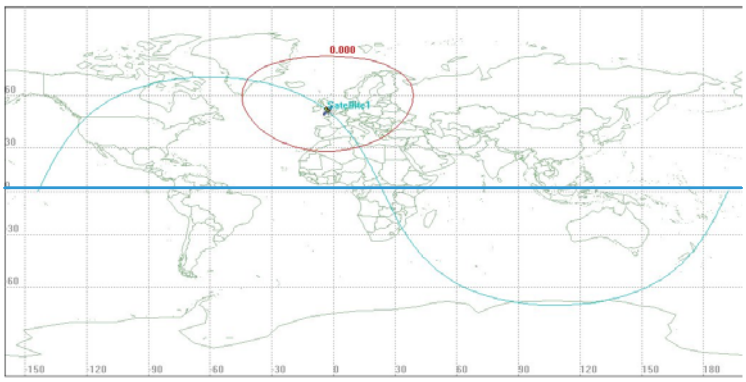


Figure A7-14 presents the satellite field of view. A wide geographical area is covered by the satellite field of view at any given point of the orbit. For this area, the average instantaneous ship count is 22 000 respectively as shown in Figure. A7-15. The ship count is based on combined received terrestrial and satellite data for AIS class A.

FIGURE A7-15

Field of view case for ship instantaneous number

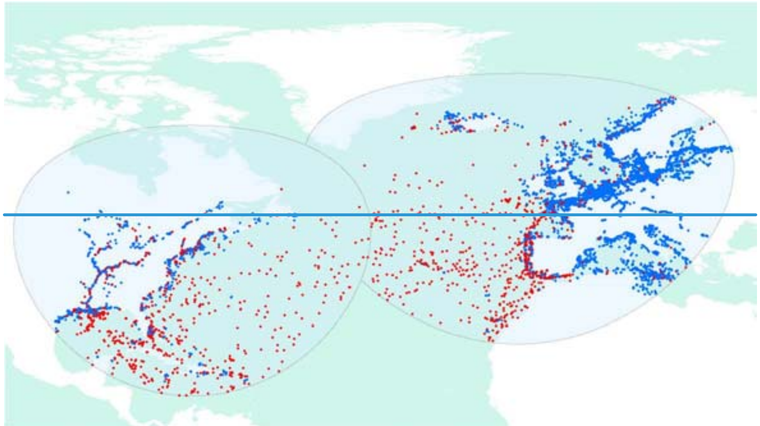


Figure A7-15 is indicative of the AIS received by terrestrial stations is displayed in blue while AIS received by satellite is displayed in red.

8.2.1 VHF data exchange satellite downlink characteristics

The power flux density mask to be respected is (as also presented in Table A4-1 of Annex 4).

$$PFD(\theta°)_{(dBW/(m^2*4\ kHz))} = \begin{cases} -149+0.16*\theta° & 0°\leq\theta<45°; \\ -142+0.53*(\theta°-45°) & 45°\leq\theta<60°; \\ -134+0.1*(\theta°-60°) & 60°\leq\theta\leq90°. \end{cases}$$

where θ is the angle of arrival of the incident wave above the horizontal plane, in degrees.

Which is tabulated as follows:

TABLE A7-8

Tabulation of pfd mask

	dBW	**A = −36.0 dB**	**A = +14.0 dB**
Theta	Flux/4 kHz	Flux/1 Hz	Flux 100 kHz
0	−149.00	−185.00	−135.00
5	−148.20	−184.20	−134.20
10	−147.40	−183.40	−133.40
15	−146.60	−182.60	−132.60
20	−145.80	−181.80	−131.80
25	−145.00	−181.00	−131.00
30	−144.20	−180.20	−130.20
35	−143.40	−179.40	−129.40
40	−142.60	−178.60	−128.60
45	−142.00	−178.00	−128.00

Commenté [JC100]: Where is table referenced in text?

TABLE A7-8 (*end*)

	dBW	A = −36.0 dB	A = +14.0 dB
50	−139.35	−175.35	−125.35
55	−136.70	−172.70	−122.70
60	−134.00	−170.00	−120.00
65	−133.50	−169.50	−119.50
70	−133.00	−169.00	−119.00
75	−132.50	−168.50	−118.50
80	−132.00	−168.00	−118.00
85	−131.50	−167.50	−117.50
90	−131.00	−167.00	−117.00

FIGURE A7-16

Power flux density mask

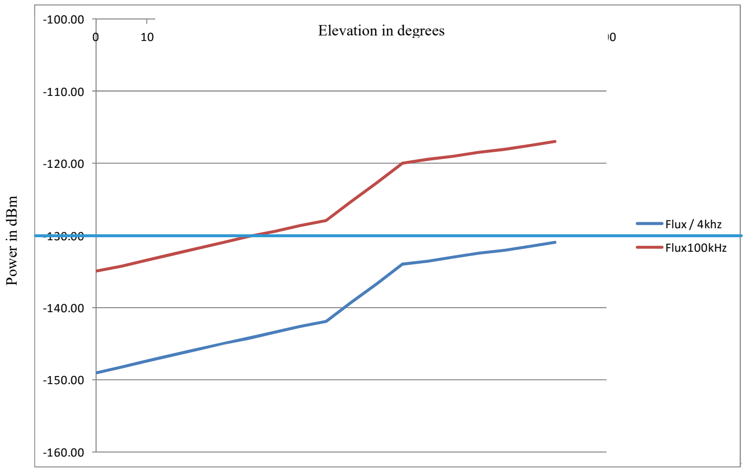


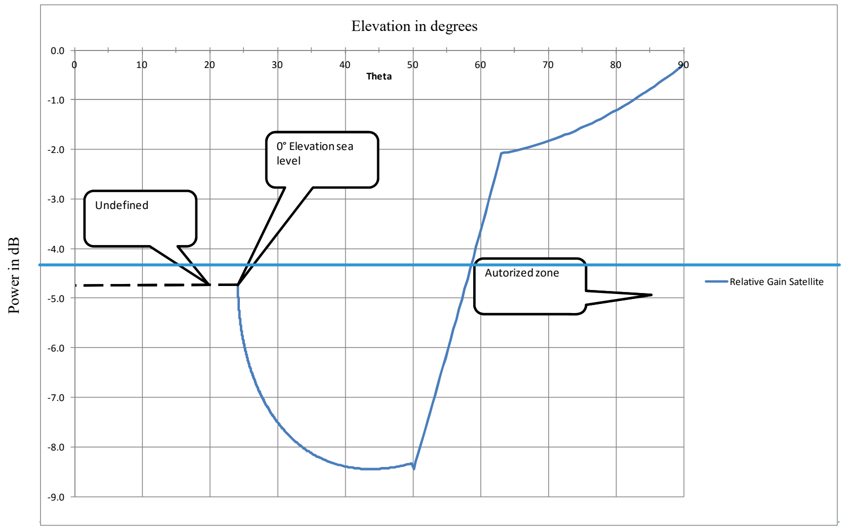
Figure A7-16 depicts the PFD mask in dBm as a function of elevation in a reference bandwidth of 4 kHz and in 100 kHz bandwidth.

The corresponding e.i.r.p. mask seen by the satellite corresponds to a transformed version of the PFD mask dictated by the Earth-satellite geometry.

Figure A7-17 shows the e.i.r.p. mask which is symmetric around the nadir direction (90° angle in the figure).

~~FIGURE A7-17~~

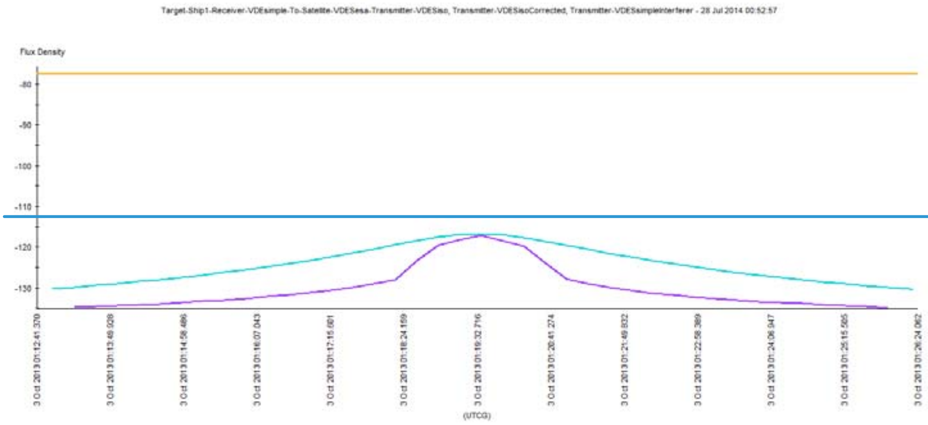
~~**Satellite equivalent isotropic radiated power mask**~~



~~Assuming a circularly polarized downlink signal from the satellite meeting the e.i.r.p. mask in Figure . A7-17, then the PFD in 100 kHz seen in an overhead pass by a ground terminal is shown as a violet curve in Figure. A7-18. In this figure the signal power of a nearby ship (shown in yellow) is also presented as a benchmark reference. The green line represents the realization of an antenna on the satellite compliant with the e.i.r.p. mask.~~

~~FIGURE A7-18~~

~~**Receiver carrier input for a 0 dB gain antenna.**~~
~~**Isoflux and compensated satellite transmitter antenna + nearby ship**~~



8.2.2 VHF data exchange satellite receiver characteristics

On the receiver side, the ship's system temperature is considered to be between 630 K (noise figure of 3 dB and 2 dB of cable loss) and 1 500 K. Variations can occur, but it is not expected that the system temperature falls below roughly 900 K in a standard installation. The system temperature accounts for the noise source integrated in the antenna patterns. Some on board 'industrial' noise is yet to be added, but will be ignored for the remainder of the document.

8.2.3 "Ideal" receiving antenna

For the sake of completeness, the receiver antenna mask that would allow the received signal to be at constant power level at the receiver input is calculated and shown as a function of elevation angle in Figure. A7-19.

FIGURE A7-19

"Ideal" receiver antenna mask, zenith is 90°

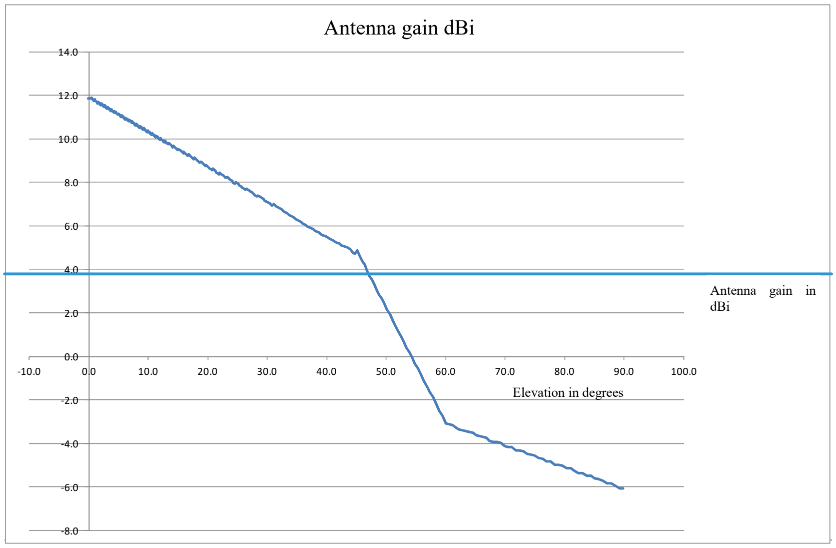


FIGURE A7-20

Received carrier power for a receiver with an "ideal" antenna

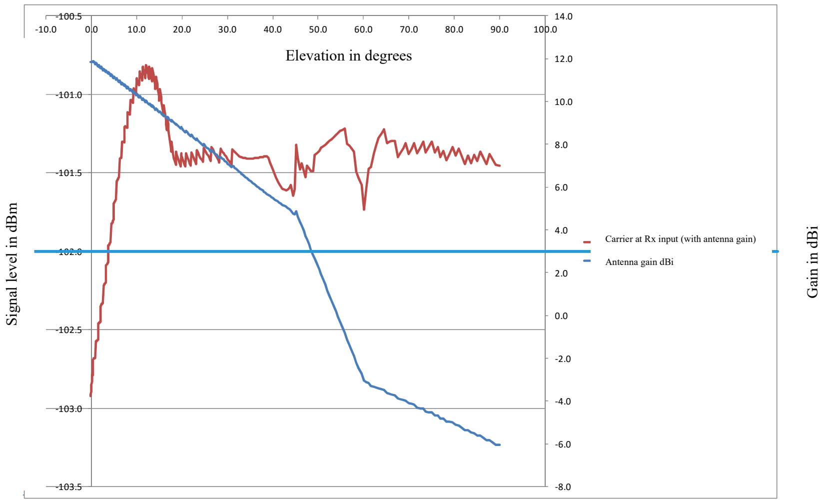


Figure A7-20 shows the received signal power in dBm at the input of a receiver with the "ideal" receiving antenna as a function of elevation. The link analysis is computed using professional commercial software tools for satellite communications that account for the signal propagation impairments.

The software tool however, does not account for possible loss of power strength at very low elevation (< 1°). The power loss could be as high as 6 dB due to reflecting surface of seawater, mainly in circular or horizontal polarizations. It is worth noting that the signal power at the receiver input is around −101 dBm, and this is 3 dB lower than the Recommendation ITU-R M.1842 recommended sensitivity for 16-QAM for ship stations.

FIGURE A7-21

***E_b/N_0* compensated patterns for "ideal" antenna**

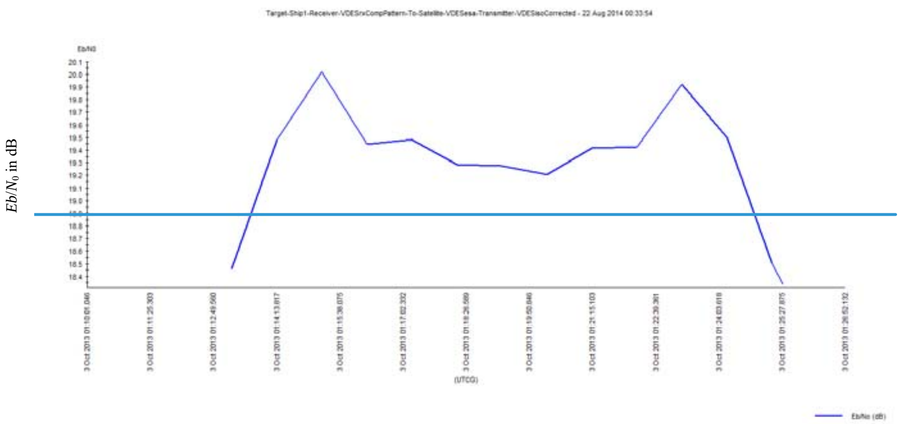


Figure A7-21 shows the corresponding E_b/N_0 observed for the 100 kHz carrier in an overhead pass for the "ideal" antenna.

8.2.4 Realistic receiving antenna

Four different antennas are considered:

– The 0 dBd point in the Recommendation ITU-R F.1336 antenna pattern and vertical polarization (antenna 1)

– A 1.25 λ vertical antenna (commercially available antenna, computed pattern when mounted on the top of the bridge a 200 m long tanker), vertical polarization (antenna 2)

– A satellite dedicated Turnstile antenna, with right hand circular polarization (RHCP) (antenna 3)

– A hemispherical 0 dBi gain antenna, vertical polarization (antenna 4).

Using professional software tools for satellite communications, simulations have been carried out to determine the carrier power level at the receiver input and to determine the E_b/N_0 in the following cases:

– Overhead pass

– Side pass

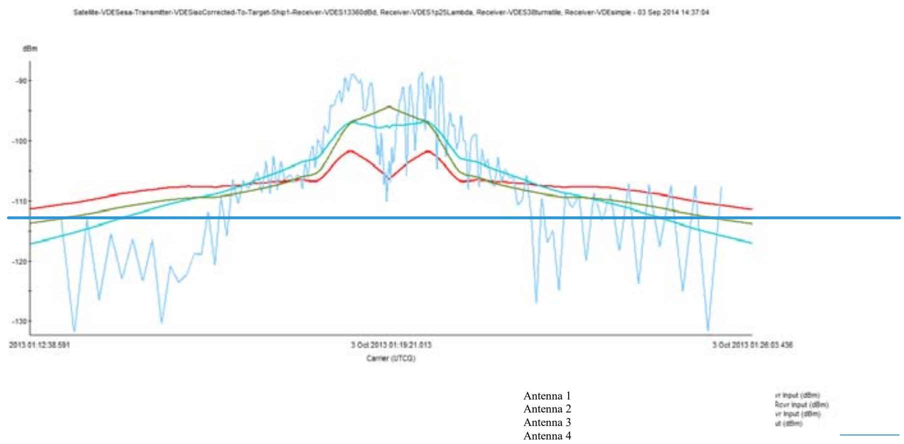
– Very low pass.

Results corresponding to each scenario are reported in the following sections.

8.2.4.1 Overhead satellite pass

FIGURE A7-22

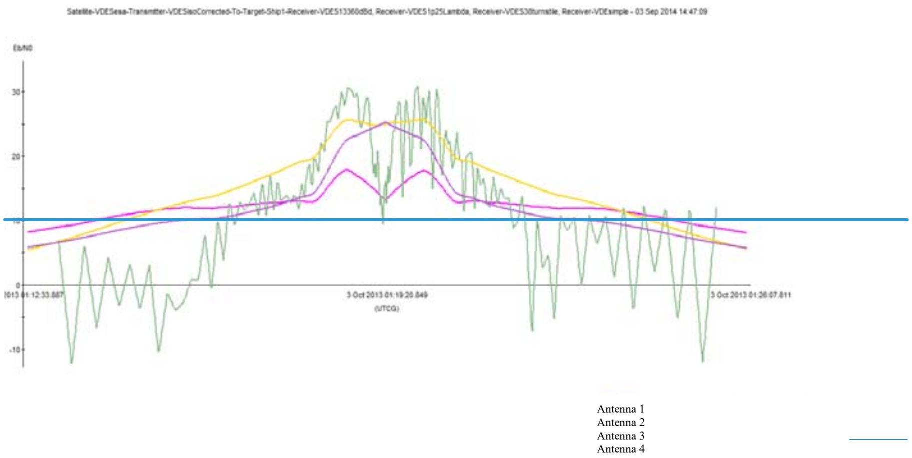
Overhead satellite pass, carrier level at receiver input



Commenté [JC101]: Where is this referenced in the text?

FIGURE A7-23

Overhead satellite pass, E_b/N_0 at demodulator input



Commenté [JC102]: Where is this referenced in the text?

8.2.4.2 Side satellite pass

Consider a 16° elevation pass, the signal power and corresponding signal quality measured in E_b/N_0 are presented in the following figures A7-24 and A7-25. Due to the variation of the signal strength at the receiver over time (due to the change of elevation and distance), the signal may fall below the detection threshold.

The use of highly robust waveform (as a combination of modulation, coding and frame structure) can potentially improve the performance at the expense of reduced throughput.

FIGURE A7-24

Carrier level at receiver input, side satellite pass

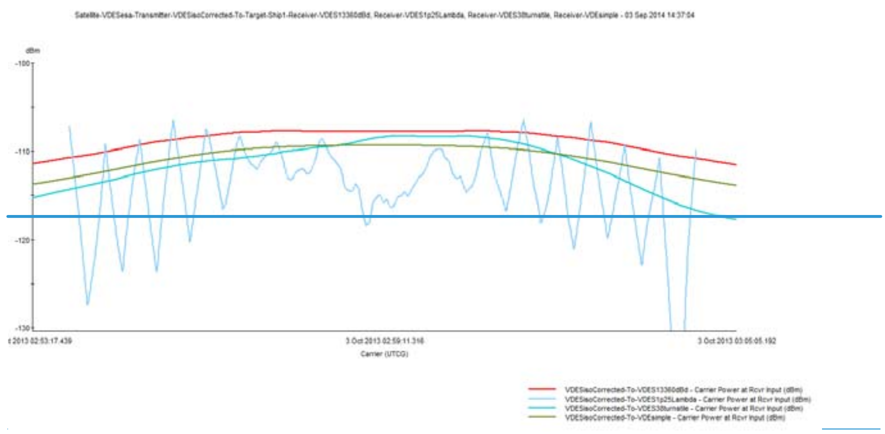
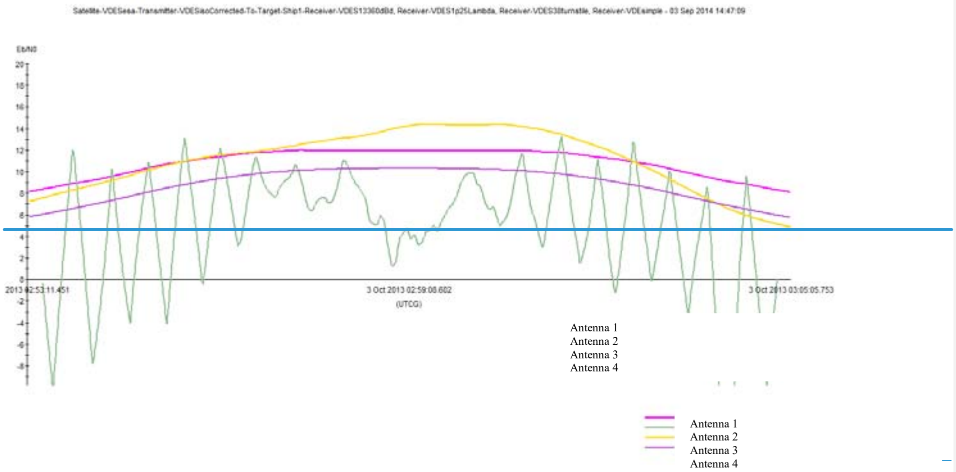


FIGURE A7-25

E_b/N_0 at demodulator input, side satellite pass



8.2.4.3 Very low side satellite pass

Results for a very low side pass (below 5° elevation) are presented in Figures belowA7-26 and A7-27.

FIGURE A7-26

Carrier input at receiver input, very low side satellite pass

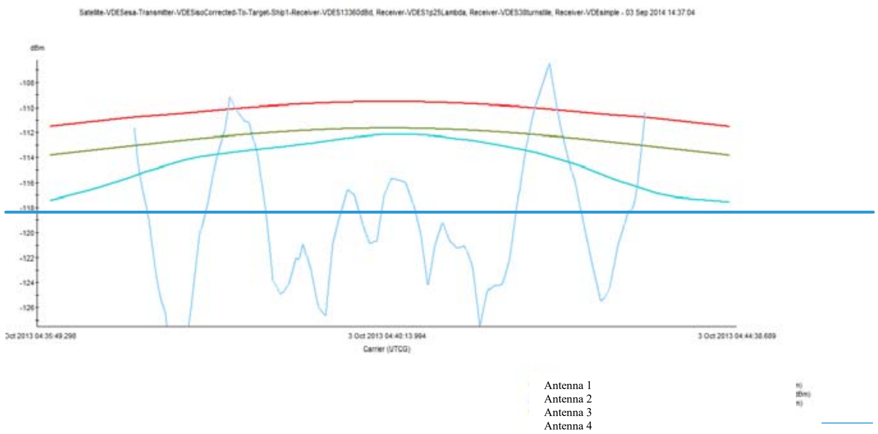
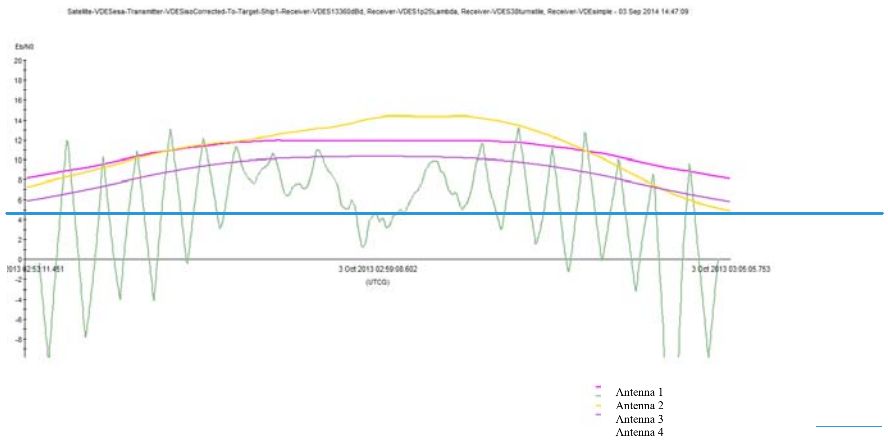


FIGURE A7-27

E_b/N_0 at demodulator input, very low elevation side satellite pass.



8.2.5 Waveform choice

As shown in previous sections, for a realistic antenna the signal to noise ratio at the input of the receiver can vary considerably as a function of elevation angle. The choice of the waveform modulation, coding and frame structure has a significant impact on the link throughput and its availability.

The decision on continuous versus intermittent transmission of the signal will impact the acquisition, tracking and the overall performance (bit rate, probability of error, etc.) of the VDE satellite broadcasting. At the system level, a time slotslot-based transmission (time division) may increase the complexity of the satellite-terrestrial system interactions and reduce the overall efficiency. However, the coexistence of VDE broadcasting and terrestrial shore-to-ship or ship-to-ship may also impact the detection performance of the terrestrial signal.

The choice of modulation scheme has an impact on the efficiency of the power amplifier on board of the satellite. The use of (quasi-) constant envelope reduces the peak to average power ratio and allows the transmitter to operate at a more power efficient mode with less signal distortion.

In order to facilitate synchronization and signal detection at the receiver, the use of known symbols (as pilot or preamble) is essential as part of the air interface definition.

The use of data sequence randomization (scrambling) facilitates the synchronization and mitigates spectral abnormality.

A system capability to allow more than one coding rate (and modulation scheme) may provide more flexibility in the system dimensioning and service availability.

There are a number of existing open standards with air interface specifications, such as Digital Video Broadcasting via satellite DVB-S2x , DVB-SH and DVB-RCS2, that offer mature technical solutions as a starting point for such design trade-offs. The performance characteristics of DVB-RCS2 waveforms are reported in Table A7-89. Figure A7-28 presents the spectral efficiency (information bits/symbol) as a function of E_s/N_0 for these waveforms.

Note: DVB-RCS2 reference: ETSI TS 101 545-1 V1.2.1 (2014-04) available at: http://www.etsi.org/deliver/etsi_ts/101500_101599/10154501/01.02.01_60/ts_10154501v010201p.pdf.

Commenté [JC103]: Confirm ref

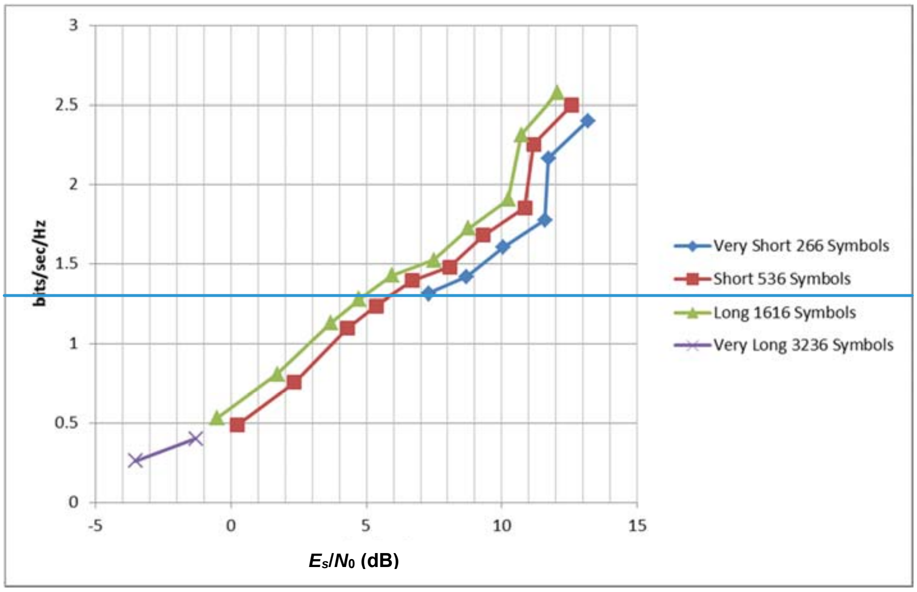
TABLE A7-9

Waveform efficiency in additive white Gaussian noise channel

Frame Size (symbols)	Guard (symbols)	Payload (bits)	Efficiency (bits/symbol)	E_s/N_0 @ PER=10^{-5}
266	4	408	1.51	7.3
266	4	440	1.63	8.71
266	4	496	1.84	10.04
266	4	552	2.04	11.59
266	4	672	2.49	11.73
266	4	744	2.76	13.18
536	4	304	0.56	0.22
536	4	472	0.87	2.34
536	4	680	1.26	4.29
536	4	768	1.42	5.36
536	4	864	1.60	6.68
536	4	920	1.70	8.08
536	4	1 040	1.93	9.31
536	4	1 152	2.13	10.85
536	4	1 400	2.59	11.17
536	4	1 552	2.87	12.56
1 616	4	984	0.61	–0.51
1 616	4	1 504	0.93	1.71
1 616	4	2 112	1.30	3.69
1 616	4	2 384	1.47	4.73
1 616	4	2 664	1.64	5.94
1 616	4	2 840	1.75	7.49
1 616	4	3 200	1.98	8.77
1 616	4	3 552	2.19	10.23
1 616	4	4 312	2.66	10.72
1 616	4	4 792	2.96	12.04
3 236	4	984	0.30	–3.52
3 236	4	1 504	0.46	–1.3

FIGURE A7-28

Spectral efficiency of DVB-RCS2 waveform



3
2.5
2
1.5
1
0.5
0
-5
0
5
10
15
bits/sec/Hz
E_s/N_0 (dB)
Very Short 266 Symbols
Short 536 Symbols
Long 1616 Symbols
Very Long 3236 Symbols